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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

IRRIGATED AGRICULTURE IN THE SAN LUIS VALLEY

By V. M. CONE and ALVIN KEZER

(This bulletin, so far as it relates to irrigation, was prepared under a co-operative agreement between the Colorado Experiment Station and the Office of Experiment Stations, of the U. S. Department of Agriculture.)

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IRRIGATED AGRICULTURE IN THE SAN LUIS VALLEY.

By V. M. CONE and ALVIN KEZER

LOCATION AND TOPOGRAPHY.

The San Luis Valley lies in the south central part of Colorado. An arm of the valley extends a few miles into New Mexico, but is of little importance so far as irrigation is concerned. The eastern rim of the basin is formed by the Sangre de Cristo range, and the western rim by the Conejos mountains, La Garita hills, and the Saguache mountains. The junction of the Saguache mountains and the Sangre de Cristo range closes the valley in the north. The valley proper is about ninety miles long and forty-five miles wide, and is roughly elliptical in shape.

The principal streams entering the Valley on the west are the Rio Grande, Conejos and Alamosa rivers, and La Jara and Saguache creeks. Entering from the east are the Culebra and Trinchera rivers and Cottonwood, Spanish, Willow, Crestone, Rito Alto and Cotton creeks. San Luis creek flows south from the upper end of the Valley. The streams on the east are small and usually lose themselves in the sand a short distance from their canons except when flooded. The streams on the west have much larger drainage areas and carry more water than those entering

This bulletin is based upon results obtained from field investigation and experimental farm work in the San Luis Valley, and is intended to be a popular presentation of those results. The Colorado Experiment Station, in co-operation with the Office of Experiment Stations of the United States Department of Agriculture, has been carrying on experiments and field work in the San Luis Valley for the past three years. Field plot experimental work in crops and irrigation methods have been conducted on the farms of the Costilla Estates Development Company, with headquarters at San Acacio. In this location three farms of forty acres each were divided into plats, upon which crop, soil and irrigation experiments were performed. The authors have spent considerable time upon experimental work and made many trips to various sections of the valley during the three seasons.

The Experiment Station is indebted to the Costilla Estates Development Company for courtesies extended which permitted the collection of much valuable data. In 1912 the experimental plats were taken care of by Mr. Roy Hice. Mr. E. H. Thomas was responsible for the resident work in 1913 and 1914. Much of the general irrigation information was collected by Mr. R. G. Hemphill during the years 1912 and 1913.

from the east. At one geologic period the Valley was the bed of a lake, and all except the recently formed soils were deposited by the waters of this lake. Streams flowing into the lake were laden with this material and deposited it in fan-shaped deltas spreading outward from their canons. Except in a few cases these fans are not apparent to the eye, and the Valley appears to be a flat, treeless plain. The streams flowing into the Valley from the west being larger, but carrying less heavy material, formed deltas more extensive and flatter than those deposited on the eastern side, with the result that the trough of the Valley is considerably east of its north and south axis. Most of the large irrigation systems are located on this western slope. Here the inclination of the land varies from 5 to 30 feet per mile except near the foothills, and is so uniform that canals are usually constructed along section lines either east or north. The Prairie Ditch runs for over 25 miles in a straight line, and it is reported that at no point was an excavation of more than two feet necessary.

The elevation of the Valley is high, its lowest point being over 7,500 feet above sea level. Practically all of the farming land is at an elevation between 7,500 and 8,500 feet. Elevations of some of the principal towns are given below.

Town.	Elevation.	Town.	Elevation.
Villa Grove	7,962 ft.	Del Norte	7,868 ft.
Saguache	7,740 ft.	Monte Vista	7,650 ft.
Crestone	7,871 ft.	Alamosa	7,536 ft.
Moffat	7,568 ft.	Blanca	8,403 ft.
Hooper	7,566 ft.	La Jara	7,597 ft.
Mosca	7,562 ft.	Manassa	7,660 ft.
San Acacio	7,737 ft.	Capulin	7,800 ft.
Jarosa	7,650 ft.		

CLIMATE.

The climate is characterized by almost continuous sunshine, very little rainfall, extremes of temperature, and a high wind movement. The mean annual precipitation is between 8 and 9 inches, varying widely from season to season and at different points, the highest recorded being 18.85 inches at San Luis in 1891, and the lowest 2.88 inches at Saguache in 1896. The heaviest rainfall of the year occurs in July and August at the time when most needed. Usually the rains are of little direct benefit to growing crops, but the streams flooded from rains in the hills afford water for irrigation for a few days.

The mean annual temperature is 42 degrees, the coldest month being January, with a mean temperature of 18 degrees, and the warmest month July, with a mean temperature of 64 degrees. The minimum temperature recorded was 34 degrees below zero, and the maximum 98 degrees above. Frosts are liable to occur any month of the year. Owing to the high altitude and rare air, these extremes of temperature are not keenly felt.

The most disagreeable feature of the climate of the Valley is the high wind, the general direction of which is toward the north-east. In some of the lightest soils the wind does some damage to newly planted crops, since it blows steadily for days at a time.

SOILS.

In appearance the San Luis Valley is a vast plain. To the eye it appears to be level and devoid of hills and irregular slopes. Actually, it is the basin-shaped bottom of an ancient lake, which at present appears as a treeless plain surrounded by high and rugged mountains. The surface slopes are unusually uniform and gradual. Close to the eastern edge, which is the low portion of the Valley, or Valley trough, the slopes are so slight that drainage is very poor, causing considerable areas of seeped land, some swampy portions, and shallow basins filled with alkali lakes.

A large proportion of the soils of the Valley is sand, sandy loams, and gravels, underlaid at from two to four feet of the surface with gravel more or less porous in nature. The soil materials were deposited in large part at the geologic time when the San Luis Valley was occupied by a lake. These materials were carried from the slopes of the adjacent mountains by the torrential streams which flowed into the ancient lake. The so-called recent soils have been deposited by the streams since the drainage of the lake, which occurred when the canon of the Rio Grande was cut thru in past geologic time. This ancient soil material was laid down in alternating layers of clay, sand and gravel. In many places at the present time the surface has been worked over and new material deposited by the streams. Some of this material is known as adobe, being of very fine texture and extremely difficult to work.

These adobe or clay soils are classed as "heavy." As a total area they are comparatively unimportant in the Valley acreage, since they are usually confined to the bottoms and flood plains of the larger streams. Away from the streams, towards the slopes in the foothills, the soils are a little lighter in texture. Most of the heavy soils are comparatively recent stream deposits—that is, they have been deposited by present streams since the drainage of the lake which once occupied the present San Luis Valley.

Quite a large number of soil types occur, many of which have a considerable distribution. The soils deposited as the result of the work of the Rio Grande commence at Del Norte and extend eastward to Mosca, Hooper and Alamosa, and westward to the mountains. Most of these soils are rather porous and gravelly, underlaid by gravelly subsoils. In color they are mostly reddish brown. These soils have been called by the Bureau of Soils the San Luis Series.* In this region are found sands, sandy loams and loams, which the Bureau of Soils has called San Luis Sand, San Luis Sandy Loam, and San Luis Loam, respectively.

The San Luis Sand extends from the face of the mountains to the vicinity of Center and Monte Vista and eastward from those towns in narrow belts as far as the Valley trough. The type is porous and easily worked, being derived from the volcanic rocks on the adjacent mountains. The lighter portions are subject to wind drifting, and frequently form slight ridges or dunes. The subsoil is gravelly and occurs at depths of two to four feet. This soil never becomes sticky when wet, water penetrates it readily and drainage is rapid where the slopes and other conditions permit. Some of the lower slopes, due to insufficient natural drainage conditions, are swampy and alkalized. New lands of this type frequently have a cemented area or layer which occurs at about the depth of the rainfall's penetration. The cemented area has been caused by the washing down of soluble materials from the surface and their deposition in a layer at the bottom of the zone of percolation. Irrigation has dissolved these cementing materials and on old irrigated lands this layer, sometimes called hardpan, is not noticeable.

In this area the next most extensive type of soil is the San Luis Sandy Loam. This contains more fine material than the San Luis Sand previously described but is, on the whole, rather coarse and carries considerable gravel. The surface layer is from 18 to 36 inches in depth underlaid by coarse gravelly subsoil. It is quite sticky when wet, especially as there are often streaks of heavier material in the surface. Except in the lower lying districts this type is naturally well drained.

The San Luis Loam occurs in limited patches on the lower rivers and usually upon the low slopes adjoining such areas. The soil is rather heavy and contains a great deal of the finer material carried down by mountain torrents, or washed from higher lying soils. It looks much like San Luis Sandy Loam, but contains a

* Soil Surveys of the San Luis Valley, Colorado Field Operations, Bureau of Soils, 1903. Circular No. 52, Bureau of Soils, 1912.

considerable amount of finer material, thus becoming sticky when wet. Stickiness is probably increased by the presence of alkali salts and by the absence of coarse sand or fine gravel in the surface layers. It is usually underlaid at a depth of two to three feet with sand or sandy loam which grades into the usual gravel underlying most of this region. This soil is very rich. When well drained it will produce heavy crops of grasses, alfalfa and grains, but much of it is not now available for cropping because of seepage and alkali.

The so-called Rio Grande series occurs in narrow belts along the Rio Grande. The series includes Sandy Loams, Loams and Clays, the first-named being the most extensive type. All of these soils are dark brown to black in color and usually have considerable organic matter in their native condition. The surface soils contain very little gravel, but generally at a depth of two feet or slightly over, they are underlaid with the prevailing gravel layer or layers peculiar to this region.

The surface slopes of the Rio Grande types are gentle, favoring irrigation, though they are frequently cut up by old stream courses or banks of gravel. Much of their area is subject to overflow or is flooded to increase the growth of wild hay. If protected from overflow and excessive irrigation, Rio Grande Sandy Loam is one of the best adapted soils for potatoes, alfalfa and truck crops.

The heavier Rio Grande types are also subject to overflow. They are very sticky and puddle easily, and these adverse physical conditions frequently are made worse by considerable quantities of alkali. When worked in just the right way and at the right time they give good crops of grass and wheat. However, their management is difficult as they require artificial drainage, very careful irrigation and plowing and other cultivation at just the right moisture point—conditions difficult to obtain.

The San Luis and Rio Grande Series occupy the western and southern parts of the valley and include the more important agricultural types. The soils of the northern part of the Valley are somewhat heavier in texture—that is, they contain much more fine material. They were probably deposited by slower moving streams as the present grades of the streams are much lower than those in the western and southern parts of the Valley. The lime content of the soils is also less.

The soils in this section are chocolate brown to light brown in color, although occasionally they will be found almost gray in considerable patches. Close to the mountains and on the Valley slopes the soils are gravelly to sandy gravelly loams, but on the flatter Valley floor they run to loams and clays. Rather heavy percentages

of alkali are encountered which is mostly composed of sodium sulphate and sodium chloride. Some magnesium sulphate also occurs.

In the vicinity of the alkali lakes, in the eastern part of the Valley, there is an occurrence of some black alkali or sodium carbonate as well as some sodium bicarbonate. Outside of this small locality the alkalis of the Valley are mostly the so-called white alkalis and are occasionally in sufficient quantities to be injurious to vegetation. They come to the surface when the land is waterlogged or seeped. Probably more damage is done by seepage in many of the wet alkali sections than by the white alkali itself, although the percentages sometimes run high.

With few exceptions, the soils of the Valley are deficient in organic matter, the incorporation of which is one of the big problems of farming and successful soil management.

IRRIGATION.

Probably the first irrigation in Colorado was by the civilization which gave rise to the cliff dwellings still extant in the extreme southwestern portions of the state, but the first modern irrigation was probably in the San Luis Valley. The first development was in the extreme southeastern part of the Valley and was small in comparison with the present irrigated acreage. Some irrigation systems now in use date back as far as the early fifties, but until 1880 development was slow. The ditches were taken out by individuals or by a few farmers associated together. During the period from 1880 to 1890 a majority of the present ditches of the Valley were constructed. Little was done from 1890 to 1905, but since then new systems have been built and many of the older ones improved by the construction of reservoirs and by ditch betterments.

There are at present in the Valley approximately 1,100 ditches with adjudicated water rights. These aggregate an appropriation of 15,873.82 second-feet, while about a hundred other ditches have unadjudicated claims for water. There are about 2,000 miles of ditches and principal laterals. Authorities differ as to the area of the land irrigated in 1914, this being variously estimated at from 500,000 to 790,000 acres. Five hundred thousand acres is perhaps a conservative approximation, having been arrived at by checking up the records of agents in the field during that season. It is believed that the number of acres which can be irrigated is approximately 800,000.

During the early days of irrigation development in the Valley nearly all of the water used was secured by direct diversion from the streams, but during the past few years seventeen reservoirs with an aggregate capacity of over 260,000 acre-feet have been

built, materially increasing the supply of water available during the irrigation season since they store water in flood times and hold it till times of normal slack stream flow.

In the western and southwestern portion of the Valley, there is considerable artesian water. Owing to the very porous nature of the soils small reservoirs cannot be built economically and successfully for storing the flow from these wells. There are between 5,000 and 6,000 of these artesian wells. Roughly, the wells average a flow of 40 gallons per minute. This is much too small for direct application except on small acreages, such as garden patches. Some of the wells, however, have much heavier flows. Despite the aggregate flow of 450 second-feet the acreage irrigated is extremely small, totaling not over 2,000, mostly on gardens and small patches. Owing to the manner in which the wells have been cased—that is, for a short distance only—it is not feasible to cap the wells and stop the flow when the water is not needed for use. Consequently the discharge from these wells has created local swampy areas and has caused considerable trouble without furnishing very much direct benefit except in the way of water for domestic purposes.

Data for 1912 show practically 300,000 acres irrigated by surface flooding. Sub-irrigation is employed directly on about 130,000 acres or approximately one-fourth of the irrigated acreage. The sub-irrigated lands are almost exclusively those irrigated from waters taken from the Rio Grande, there being only about 5,000 acres in other districts which are sub-irrigated. Furrow irrigation is used on 24,000 acres, principally for cultivated crops such as potatoes, beets and other roots, and also on lands too steep for flooding. The border and check methods are used on about 4,000 acres.

As stated above, the acreage watered directly by sub-irrigation methods is approximately one-fourth of the total irrigated acreage. However, there is no way of telling what acreage is indirectly influenced by the sub-irrigation practice. The water level has doubtless been raised over a very much larger area. Near the upper portions of the sub-irrigated belt the water table must be raised from 20 to 30 feet each season to bring it into the root zone. This practice has naturally resulted in an undue rise of the water table in lower lying lands and in seeping and swamping the lowest. Sub-irrigation can hardly be improved upon where ideal conditions of soil and slope obtain, but ideal conditions are very rarely encountered. When only a few farmers were irrigating with sub-surface methods no bad results followed, but when large areas were so irrigated it was found that sooner or later the farmer on the lower land was drowned out. Perfect control of the water level is impossible

to secure so that sub-irrigated fields are usually either too dry or too wet. The rise of the sub-soil water following sub-irrigation has carried up alkali which has accumulated at the surface—in fact, sub-irrigation has produced more pernicious results in this respect than any other method of irrigation practiced. While sub-irrigation is very easy on the irrigator and enables one man to irrigate a large acreage at a cheap labor cost, it is very hard on the land and may be very hard on the crop. Practically all of the land which has been subjected to one system or another of drainage was formerly watered by sub-irrigation, but is now being surface irrigated.

To change from sub-irrigation to surface irrigation, it is only necessary to enlarge the supply ditches and build the field laterals closer together. For surface irrigation, especially on the lighter soils which slope, all water should be run across narrow strips of land—that is, the field laterals should be close together. In porous sandy soils the water should be run across the gentlest slope so as to reduce washing to the lowest possible limit. A change from sub-irrigation to checks or borders could be made with equal ease, the only difficulty being the expense of constructing levees. Rectangular and border checks are now being used in several sections of the Valley in alkali reclamation work.

Irrigation, especially on the sandier lands, which do not have a high water-holding capacity, must be rather frequent to give best results. Lands which tend to form a crust should be irrigated prior to the seeding, where it is necessary to “irrigate up” the crop. If this is done cultivation can be given before seeding and the seeding operation itself effects some cultivation which will produce a surface mulch and effectually break up the crust. On lighter soils where a crust is not formed there is a tendency for the formation of a natural mulch. On such soils to “irrigate up” the crop it is best to plant the crop and irrigate after seeding, because the soils will not hold moisture in contact with the seed long enough if they are irrigated first and seeded afterwards.

Until recently very little land has been leveled for irrigation. What leveling was done consisted in running a field float over the surface after plowing. Now, however, considerable land is fairly well leveled with slips and fresnos after plowing. Usually such work pays well because it permits putting all of the land into growing crop.

Clearing land for irrigation was formerly done by burning off the sagebrush or hacking it out with grub hoes. Now the land is usually broken with heavy plows pulled by tractors, and the brush is raked off. Preliminary leveling done and a crop or two planted, the ground will be settled enough for final leveling.

DRAINAGE.

The best evidence available shows that there are approximately three-fourths of a million acres needing more or less artificial drainage. Possibly 25,000 acres are now provided with drainage systems. A large amount of the seeped land is damaged by irrigation—largely sub-irrigation. A small amount has been damaged by the flow of springs and artesian wells.

Owing to the great length of the slopes and their uniform grade drainage systems to be successful will require large districts and community effort. Drainage operations now being carried on are successful enough to warrant the statement that satisfactory drainage presents no seriously difficult engineering features. It does demand, however, widespread community co-operation.

GENERAL FARMING CONDITIONS.

The soils of the Valley have already been discussed specifically. Soil conditions for farming purposes can be summarized by stating what actually prevails. The great majority of the soils are sandy loams and gravels, underlaid by gravel. There are heavy soils in the northern part of the Valley and along the flood plains of the streams in other portions. These heavier soils often present very peculiar local conditions which are difficult to deal with but from the standpoint of the farming of the Valley they are relatively unimportant, because the area is not very great.

The gravelly subsoils where drainage is good, make the moisture situation acute since they usually cause surface soils to dry out readily, especially if the gravel comes close to the surface. Such conditions will require frequent watering in farming practice.

A general lack of organic matter or vegetable matter affects the Valley soils, except the heavier and recently formed soils along some of the stream courses. Farming practice which aims to maintain production and to increase the fertility of these soils must include some scheme for incorporating vegetable matter (commonly called organic matter) with the soil. Owing to the altitude, the seasons are short and the nights cool so that rotting of organic matter is a slow process. This has led to the general impression that manure and other organic matter cannot be rotted in these soils. This is a mistaken belief. If the organic matter or manure be thoroly chopped to pieces with a disk harrow and mixed with the surface soil, it will be well incorporated with the soil when the plowing and harrowing operations are performed. The pulverized organic matter readily rots and mixes.

The general farm practice of the Valley is to plow too shallow. Deep plowing immediately before seeding will usually delay the

maturity of the crop, as it keeps the growth green later in the season, consequently deep plowing should be done at a considerable time before the crop is seeded. Fall plowing on lands intended for spring seeding, or at least very early spring plowing, is necessary where deep plowing is practiced. In certain localities the soils are so light that they blow readily in the prevailing winter and spring winds and it is sometimes necessary to leave such soils unplowed so that they may be protected by the stubble or other summer growth. Likewise, in some sections the winters are normally so dry that the furrow slice will be entirely dried out where fall plowing is practiced and spring irrigation will be necessary to germinate the seed. Prevailing practice differs thruout the Valley, therefore, according to the prevalence or absence of the conditions referred to. In those sections where conditions would permit more fall plowing for spring crops it would cause a better distribution of labor and larger crops.

Altho the San Luis Valley is served by two railway lines, it is necessarily subject to rather high freight rates, as lines must cross mountain passes to get into the Valley. This condition, coupled with the short season which limits the class of crops which can be grown, somewhat affects the most profitable farm practice. Cash crops in excess of local consumption should not be grown except those which will sell for an exceedingly high price on outside markets. Consequently, the best farm management to be followed in general will encourage the production of feed so that the crop is "marketed on the hoof"—in other words, to permit livestock to convert the relatively cheap hay, grain and other feed into relatively concentrated and high-priced animal products. From the standpoint of good farm practice, a great deal of these crops should be fed upon the individual farms in order that the manure may assist in the maintenance of soil fertility.

Large areas of the feed crops of the Valley are now grazed in the field. This is especially true of peas and pea-grain mixtures. Such practice is exceedingly wasteful of feed, since a large amount of it is blown away by the high winter winds and much of it is tramped into the ground. Moreover, during the winter, snow frequently covers the fields for days at a time. Under such conditions animals will often lose more in four or five days than they can gain in twenty, but where the crop is harvested and fed in lots, the waste is largely stopped.

Over a considerable portion of the Valley summer range in the foothills and mountains is available. Such a condition fits in wonderfully well with the production of hay and grains for feed upon the individual farms. It is estimated that 250,000 to 300,000

lambs are fed yearly and if the feeding industry were properly developed the number of sheep, cattle and hogs now sent out of the Valley could be very largely increased. This could probably be accomplished by increasing the amount of stock on the smaller land holdings, rather than by increasing the large herds already in the valley. No one kind of stock holds any particular advantage over the others, altho cattle, sheep and hogs will constitute the chief market for feed crops produced.

Even in sections where livestock feeding is undertaken on a large scale it will be necessary to practice some sort of rotation by which green manure crops may assist in building up soil fertility. The best of management cannot keep the soil in high productivity by reliance solely upon the animal manures available for fertilizing purposes, since the supply of these is, in any circumstances, limited.

Crops capable of cultivation are necessary because of the prevalence of weeds and occasional plant pests and cultivation must be clean to keep down undesired vegetation, simply as a protection of the moisture supply. Incidentally, such cultivation prevents the formation of a surface crust and the moisture losses and poor physical conditions which result from such formation.

ROTATION.

In starting a rotation it must be kept in mind that perennial crops, such as alfalfa, should be seeded only on well-leveled land, consequently, in starting a rotation on new land or on old land which is improperly leveled, annuals should be used at first, thus permitting time being spent for proper leveling of the land for irrigation. Peas is one of the best crops available for the first planting on new land or to start a rotation on old land, is an excellent feed crop, and is also an annual. Alfalfa should never be seeded until the land is well leveled, because poor levelling results in irregular stands and bad conditions for watering—some parts will be killed out because of excess water, and others will do poorly because of a lack of water. Since alfalfa is a perennial and will probably occupy the land for several years it should be put in with that expectation. A rotation may then be practiced on the portion of the farm not in alfalfa, while the latter may stand until its yield commences to weaken. In other words, alfalfa should form part of a long rotation, while the rotation of peas, grain and cultivated crops should be shorter. In the shorter rotation, peas or pea-grain mixtures should be the first crop on the land. Potatoes, if grown at all, should follow peas or alfalfa. Where peas is grown some trouble is experienced with weeds, especially if the crop is grazed. Harvesting the peas takes the weeds off before seeding, permits early

fall plowing, and gives much the same effect as a cultivation, since it cleans the land of weeds and permits an actual cultivation in the shape of plowing.

Grain for the most part should be grown only for feed or seed. A small amount can be reserved for a cash crop to supply local demands. Where grain is used it should follow peas and pea-grain mixtures, or alfalfa where old fields are being broken up and new stands established.

At present there is a strong tendency to farm larger areas than is advisable with the help and capital available. In most cases a reduction of the size of the farms with better rotations and farm management, would result in large returns.

Sub-irrigation appeals strongly to the average man. In fact, the sub-irrigated districts have been called "the lazy man's paradise." It is the *brag* of some of these "lazy men" that they "can turn on the water and go fishing for three weeks." Sub-irrigation permitted the early settlers to farm large areas, but it resulted in the destruction of the fertility or the seeping of the lands themselves. Surface irrigation, while requiring more work, will *live* much longer and return heavier crops. Sub-irrigation on new lands when first applied will often produce enormous crops, but the yields are certain to run down, except under the most favorable conditions, unless ways of keeping up the fertility are employed. This means that more capital and more labor must be applied to individual units of land to even make profits over most of the districts where bonanza farming formerly prevailed. There has been a noticeably marked change in sentiment on this matter the last few years.

It is fundamentally important that farmers in general raise more of their own living. The hardy garden vegetables do wonderfully well under irrigation and possess a quality scarcely to be surpassed, yet there are not nearly so many gardens as there should be. Every farm should have a good garden and, whether the general farm crops are fed or not, each farmer should have some chickens, a few cows, and a few pigs so that all eggs, butter and meat used in the home will be produced on the farm and small surplus of poultry and dairy products may help reduce the grocery bill.

The leading farm crops in the Valley are wheat, oats, barley, native hay, field peas, and potatoes. Alfalfa has increased remarkably in the last three years, and sweet clover has attained a wide distribution. Sugar beets were formerly grown, but their production has been abandoned, not because they were not adapted to Valley conditions and soils, but because the population was not ready for the intensive garden culture necessary to grow sugar beets suc-

cessfully. Some planning for the future was necessary so that the organic matter in the soils might be built up. Deep plowing and frequent cultivation were needed for success, in addition to a great deal of hand labor. These requirements were not met in the Valley, and the beet industry has been a failure. Disease has made potatoes an uncertain crop. They were formerly staple.

ALFALFA.

It was formerly supposed and quite commonly asserted, that alfalfa could not be successfully grown in the San Luis Valley, but the folly of this belief has been amply demonstrated in the past few years, and it is now known that the crop can be grown practically everywhere in the Valley. Fields of some years' standing may be found in nearly every section at the present time. From Del Norte on the west and Hooper and Mosca on the east; from Saguache and Moffat on the north to Antonito on the south, and San Luis, San Acacio and Eastdale on the southeast, there are successful fields of alfalfa. Many of the failures in the past have been due to a lack of understanding of proper methods of handling the crop and to improper varieties.

The altitude of the San Luis Valley is very high and the extremes of temperature and moisture are consequently great. The southern types of alfalfa and much of the so-called common alfalfa are not likely to prove successful because of their inability to stand the winter climate and the dry cold, windy springs.

Alfalfa is a deep-rooted crop. Where the root room is limited by subsoil water, the common alfalfas will not survive. The so-called hardy or northern types will grow under these conditions, but the reduction of root room causes them to feed heavily upon the surface soil, and all except exceedingly rich soils will soon be exhausted. Alfalfa is commonly supposed to be a soil improver, renovator or fertilizer. Under proper conditions this is absolutely true, but it is also true that of all the crops grown in the Valley alfalfa is one of the heaviest feeders upon soil fertility. It may be expected; therefore, that on those soils where the rise of sub-soil moisture is such as to develop a very heavy shallow root system, the crop will eventually tend to exhaust the soil fertility. Many of the Valley soils, as has already been shown, have sandy and gravelly subsoils. On such soils, when the subsoil water is allowed to recede (if it does recede) the mass of roots in this narrow zone at the surface finds difficulty in securing moisture enough for the plant to subsist upon. Growing upon these porous soils the crop is unable to put roots down into the gravelly layer fast enough to get the water needed for growth and the thick mass of roots in

the surface will soon exhaust the water supply in the limited area of the surface soil. Under such conditions the crop ceases growing and will perhaps wither and die. While proper varieties can be grown where the subsoil water is very close to the surface, they will not make as good development nor produce as heavy tonnages thru so long a period of time as will be the case when the soils are watered by correct methods. Where the farming methods are such as to provide a considerable depth of soil properly moistened, alfalfa sends out an extensive root system which enables it to draw its moisture and food supplies from large areas of the soil and subsoil. These are the conditions best suited for the proper and heaviest development of the crop.

Under best management it is not advisable to seed alfalfa on new land or on old land that has not been properly leveled. Alfalfa is a crop which will remain on the land several years. Improperly leveled land increases the work of irrigation and will often leave pockets which will receive so much water that the alfalfa will be killed. On the other hand, ridges and knolls may be left to which water cannot be supplied in sufficient quantity to keep the crop going. These conditions increase labor and reduce the yield of hay.

An additional reason exists for delaying planting on new lands. When first broken up and put under irrigation, these settle unevenly. They should therefore be irrigated at least one or two years so that these inequalities can be leveled off and settling effected by the use of irrigation water may be finished before the ground is planted to alfalfa. Such practice will do away with the evils which often appear from gopher and other rodent holes before the alfalfa is put on the land.

In San Luis Valley it is seldom advisable to use a nurse crop with alfalfa. Generally only two conditions occur where the use of a nurse crop is advisable, these being found upon the heavy abode and clay lands which tend to bake and crack at the surface. Here a nurse crop may break up the surface and enable the young plants to appear, which they might be unable to do otherwise. In sandy lands which are subject to plowing, it is sometimes advisable to put in a nurse crop to hold the surface soil. Under practically all other conditions alfalfa will do better and can be more successfully started when planted by itself.

Variety.—Both the costly experience of farmers who have made failures and the direct experiments by the Experiment Station have shown that it is not advisable to plant the southern types of alfalfa in the Valley, and, in general, even common alfalfa is not adapted to the soil and climatic conditions which are found there.

The best varieties to grow are the Baltic, Grimm, and Hardy Turk-estan, in the order given considering local preference or comparative value for the Valley conditions. Baltic alfalfa is, in a way, a selection from Grimm, but is somewhat better than the parent variety. Common alfalfa, the seed of which has been obtained from long established fields from which practically all of the non-hardy plants have been killed, can be grown to a considerable extent, but it is not advisable to use common alfalfa for seed if the hardy varieties can be obtained and their propagation effected. Such "naturally selected" common alfalfa will stand the winters very well, but it does not stand the soil water conditions nor the effects of late spring frosts, which are often accompanied with *Black Stem Rot* or *Alfalfa Blight*, as well as do the hardy types.

Preparation of Seed Bed.—One of the first considerations in the preparation of a seed bed is to have the land properly leveled. After this feature has been taken care of, the immediate preparation will depend a great deal on previous cultivation. Relatively new lands should be deeply plowed, preferably in the fall, where alfalfa is to be planted the following spring. Sometimes in preparing a seed bed it is advisable to plow deeply and thoroly for a grain crop and then disk the stubble of the grain in the fall after the grain is removed and the following spring drill the alfalfa in on the land so prepared. This is especially advisable for sandy lands, and will do away almost entirely with any need for a nurse crop. Where land has been plowed it should be worked down thoroly by disk-ing and repeated harrowings until the sub-surface is well packed, with a granulated surface to conserve moisture and to prevent, as far as possible, the winds from blowing the soil.

Sometimes there is sufficient spring moisture in the soil to germinate the seed and start the crop off. In such cases planting may be done at once. Where the soil holds insufficient moisture, as is often the case after dry winters, it may be necessary to irrigate for seeding. On heavy adobe or clay lands, or even heavy loam lands, it is advisable to thoroly level and prepare the land, irrigate, and then, just as soon as the surface can be worked, plant with a disk drill. If such a tool is not available, it is advisable to disk the surface and follow the disk with a harrow and alfalfa drill or seeder.

In the case of sandy lands it is usually best to thoroly prepare the seed bed, seed the alfalfa and irrigate afterwards, because on sandy land there is no danger of the formation of a crust and sand is not retentive enough of moisture to hold moisture in contact with the seed any great length of time consequently the seed should

be in the ground previous to the irrigation. This process is commonly called "irrigating up."

In the San Luis Valley spring seeding should always be practiced. It is usually advisable to delay seeding until the latter part of April or early in May, as the soil is then warmer and the crop will start up more vigorously if other conditions are right.

Irrigating.—The first year, especially, care should be taken in watering. The object should be to make root rather than top development. To accomplish this there must be water in the subsurface and subsoil, because the roots will not grow downward into a dry soil. Frequently very light irrigations will keep the crop growing, but will not tend to produce root development. Relatively heavy irrigations, followed by lighter ones, will tend to produce a heavy root growth.

One of the most serious dangers to alfalfa is winter killing or more properly, spring killing, due to the dry, cold windy springs. To reduce this danger, it is advisable to irrigate in late September or early October, so as to have some moisture in the ground upon the approach of winter. A crop so irrigated will start off vigorously in the spring. Irrigation should be such as to keep the crop growing energetically thruout the season. When the spring is dry, early irrigation is necessary. Where considerable winter or spring precipitation has fallen so that abundant moisture is in the soil it is advisable to withhold the early spring irrigation because the water at this season is exceedingly cold and will retard plant growth.

Usually three cuttings may be obtained in a season, or two cuttings and enough later growth to make considerable pasture, the latter often amounting in value to more than half a cutting. For this amount of growth, two or three irrigations will ordinarily be sufficient. On new land which has not been irrigated previously or on land very deficient in vegetable matter, more than one and one-half acre feet of water will probably be needed to produce maximum crops. Under most other conditions, however, one and one-half acre-feet will probably be ample to grow a maximum crop and may be found to be more than is absolutely necessary in the short seasons which prevail in these altitudes. Alfalfa will give heavier yields and will survive much longer if proper methods of surface application of water are followed. It will make better root development, and with better root development is capable of giving better yields. Sub-irrigation frequently used in the Valley holds stagnant water in contact with the subsoil for long periods. Alfalfa roots are killed out in such standing subsoil water, but they will grow to great depths in moist subsoils which do not have sufficient water to stagnate.

Harvesting.—One of the first essentials in growing alfalfa is to know when to cut it. The proper time to cut to get the greatest total yield of hay and feed for the season is when the crown shoots which are to produce the following crop make their first appearance. An examination of the crowns at the soil's surface from time to time will determine this point. The blossoming period is not a safe criterion to follow, because weather conditions markedly influence the time of blossoming. Sometimes the crop will be in full bloom before the crown shoots appear, and sometimes the crown shoots will be out before more than the first blossoms are in evidence. If the alfalfa is allowed to mature too much for any particular cutting it will retard the development of the succeeding crop. While any individual cutting will give a greater amount of tonnage if allowed to go to full bloom, the total weight of cuttings during the year will be greatest and the hay will be of much better quality if the alfalfa is cut upon the appearance of the first crown shoots.

The best method of making hay is to mow after the dew is off in the morning or afternoon; then rake with a side delivery rake very soon after the alfalfa is cut. It should only be allowed to wilt slightly before raking. The cutting process thru which alfalfa must pass is essentially drying. The leaves are the natural organs of alfalfa for getting rid of moisture. If the alfalfa is allowed to lie in the swath until the leaves are dry it takes a long time—several days—to dry the stems out. When thrown into a loose windrow with a side delivery rake most of the leaves are in the shade and will continue to evaporate moisture rapidly so that the curing or drying will take place in a very much shorter time. The alfalfa can be stacked directly from the windrow or may be cocked, depending upon the particular farm conditions. Where the old dump rake is used it is advisable to rake after the hay is slightly wilted, and put the hay into small cocks as quickly as possible, and cure in the cock. When handled in this way, especially where the side delivery rake is used, the hay can be put in the stack from twelve to twenty-four hours after cutting, which very much reduces the work and facilitates the whole process.

Black Stem Rot or Alfalfa Blight.—In the spring of 1914 alfalfa made an unusually good growth early in the season because of favorable weather conditions. A heavy frost, however, struck the Valley May 9th. A few days after this frost many growers noticed that their alfalfa was not growing properly. One of the authors, with Mr. A. C. Cooley, at that time Valley Agriculturist, drove over practically all the western and central sections of the Valley examining fields. It was found that the difficulty was

caused by Black Stem Rot or Alfalfa Blight. This disease attacks the alfalfa following a heavy frost which cracks the epidermis or plant skin on the stems, thus making it easy for the disease to gain entrance. The disease is almost never troublesome except after heavy frosts in the spring time. The only remedy known at present is to mow the hay at once, no matter what the size of the cutting, because the Stem Rot retards or prevents the growth of the crop on the land, especially if very virulent, and it may kill out the crop entirely. Mowing obviates this trouble and prevents injury to succeeding crops.

PEAS.

Field Peas, or Canada Field Peas, is one of the best crops for the Valley. Before it was discovered that alfalfa could be successfully grown field peas was almost the only legume crop successfully and generally planted. While authorities differ somewhat as to the time of introduction and as to the responsibility for the original plantings, it is generally conceded that some of the first planting was done in the vicinity of Monte Vista, and it is certain that the value of peas as a crop was first thoroughly established in this vicinity. James A. Kelly was one of the first to put out peas as a crop and to successfully feed it to stock. In 1914 peas constituted the major portion of the feed for something over 260,000 sheep fattened for market, while it is estimated that 18,000 to 20,000 head of cattle and a large number of hogs were also fattened on this crop as the principal feed.

When peas was first introduced the Valley had just reached a period when injury was being felt from continuous grain farming. Peas helped to restore the soil fertility and made a good rotation crop. It is quite probable that peas must be given credit—and a very large credit at that—for saving the agriculture of the San Luis Valley at a time when it was in extreme danger of annihilation because of reduced soil fertility.

The common practice over much of the pea district is to disk peas into the grain stubble and not plow. This method has some advantages, but on the whole is slipshod and will not produce the greatest possible results. Frequently, under the methods of sub-irrigation prevailing in some localities, this method will give greater returns than better ones, but where proper surface irrigation is employed much more satisfactory yields can be obtained where the land is properly prepared for the crop. To be successful, peas should be planted just as early in the spring as the seed can be put into the ground. In order to accomplish this to the best advantage the land should be plowed in the fall. One of the best reasons for

early planting is that peas is a cold weather crop; that is, the plants grow and make their best development in the cool spring weather. When planted late they are blossoming and developing seed at the most heated period of the season. As a consequence there is a tendency with late planting to a heavy production of vines and a light production of seed.

In order to plant early and properly it is necessary to plow in the fall or exceedingly early in the spring. The seed bed should be worked down until it is fairly compacted. The peas should be drilled in. The amount of seed per acre to give the best results will vary widely in different localities. On new lands, especially, more seed is required than on land that has grown peas for a number of years. This is due partly to soil fertility and is partly a question of inoculation. On new lands the soil is not inoculated for peas. When peas has been grown on the land for several years there is plenty of inoculating material present so that a smaller amount of seed will produce a larger number of plants.

Probably sixty pounds of seed peas per acre will be sufficient unless the crop is to be raised on new lands, where it may be advisable to plant as much as ninety pounds per acre. On many of the richer old lands which have been growing peas for a number of years, as low as thirty-five pounds per acre is amply sufficient.

Varieties.—There is an exceedingly large number of varieties of field peas, but despite this only a comparatively few have received very wide distribution. The two varieties most widely grown are the so-called San Luis Valley Stock Pea or "Mexican," and the White Marrow Fat, or Colorado White. The so-called Mexican pea is not a pure variety, but consists of a large number of mixed sorts, and for adverse conditions, is probably the best one to plant. Where conditions are good for pea growth, the White Marrow Fat will make heavier yields.

Numerous other varieties have been tried, some of which give considerable promise, but there is a large opportunity for improvement by seed selection. Considerable work has been done by individual farmers and a little work by the Experiment Station. This has not yet resulted in many new sorts, but it has been carried far enough to show that there is possibility of heavy increases thru selection breeding. The Warshauer-McClure Sheep Company of Antonio has been hand-selecting a variety. They have obtained a large white pea which matures at least two weeks earlier than the common peas. It does not make as heavy a vine growth, but pods very heavily. Farmers who have hand selected their peas claim that they have obtained heavy increases in yield over those not hand selected. The selection of high yielding individual plants to become

the mothers of varieties will probably give quick and much heavier results than any hand bin-selection that could possibly be made. In this way only high yielding plants would be kept to start the variety, while with bin-selection a certain type of seed is obtained, having both high and low yielding plants, which does not give the greatest possible increases.

Peas should be planted with a drill—preferably a disk drill. Being large seeded they can be planted from two and one-half to three inches deep, which will insure the seed moist soil, if proper care has been taken in the preparation of the seed bed. A common practice in drilling peas is to stop up every other drill hole. Thus with a drill having the shoes or drills eight inches apart the peas would be drilled sixteen inches apart where every other hole is stopped. In experimental work the past two seasons in the Valley it has been found that practically as good, and sometimes better results can be obtained by leaving all the drill holes open. For new lands, to leave all the drill holes open is better practice and for most old lands it is just as good as the other method.

The type of drill with the so-called revolving cup feed should be used for pea planting, as it will not break the seed. The fluted roller type of feed will crack a large proportion of the peas and thus be very wasteful of seed.

Irrigation.—Enough water should be present in the soil to start the crop in the spring even if irrigation must be practiced in order to put the water there. Any irrigation made should supply sufficient water for continuous unchecked growth until the time of blossoming. To produce the heaviest grain yields, irrigation should be shut off at this time. Heavy supplies of soil water after the plants are in blossom will keep the crop growing and blossoming clear up until frost. It will increase the yield of vines, but will reduce the yield of peas. The water can be handled much better and controlled much more easily if surface irrigation is used and heavier yields of both peas and vines may consequently be obtained. With sub-irrigation there is danger of getting too much water which is liable to be held on the land too late to make the best development of peas. The reason why peas disked into stubble land have apparently done better in many instances than peas planted on plowed land, has been largely due to sub-irrigation, the stubble land having prevented some of the effects of excessive moisture which usually accompanies sub-irrigation.

Harvesting.—The common practice in the Valley in the past has been to graze stock, either hogs, sheep or cattle, on the peas in the field. In general this practice is wasteful. In the first place, many of the leaves dry up and blow away, causing an actual loss

of feed. A quantity of the peas themselves is lost by tramping into the soil. There is another disadvantage: A five days' snowstorm quickly burying the peas in the field may cause more loss to the animals than they could gain in twenty days' grazing. Sooner or later all growers must practice cutting their peas, because, if for no other reason, they can get very much more feed off the same acreage where the peas are cut and properly taken care of than when they are grazed in the field. Another very decided advantage exists in cutting. Pea fields are often very weedy, especially with sunflowers, so that the crop following peas is liable to be troubled with weeds. Where the peas are cut and stacked this difficulty is not important, as cutting gets rid of the weeds, also leaving the land in shape so that it may be plowed and prepared for spring crops.

Pea-Grain Mixtures.—What has been said in regard to the preparation of the seed-bed and irrigation for peas applies equally well to pea grain mixtures. Mixtures which have been used extensively consist of pea-oat; pea-barley; pea-oat-barley; pea-wheat and pea-wheat-barley. One of the advantages of planting grain with peas is that the peas more or less thinly occupy the land and some other growth will be present anyhow, consequently the grower might just as well harvest a desirable feed by planting some of these grains with peas. Peas make a nitrogenous feed stuff and consequently make a very narrow ration, but when planted with grain mixtures a feed is harvested which is much more nearly balanced. Thus not only the tonnages are increased, but a better feed is produced.

For pea-oat mixtures on new lands, heavier amounts of seed will be needed than on land which has been growing peas for some time. A mixture of about forty-five pounds of peas with twenty to twenty-five pounds of oats; forty-five pounds of peas to twenty pounds of barley; forty-five pounds of peas to fifteen pounds of oats and fifteen pounds of barley; forty-five pounds of peas and twenty pounds of wheat; forty-five pounds of peas and fifteen pounds of wheat and fifteen pounds of barley are about right for new lands. On old lands, thirty to forty pounds of peas should be used with fifteen to twenty-five pounds of oats; fifteen to twenty pounds of barley, and fifteen to twenty pounds of wheat.

Early seeding is as important with pea grain mixtures as it is with peas alone. Oats may be killed out by frosts on exceedingly early seedings, but usually barley and wheat will withstand frosts. This has been the experience in experimental work with such mixtures.

The pea-grain mixtures should be harvested in the same manner as peas, and should be either stacked or put into the silo. The

pea plants, especially if the growth is rank, often become very much tangled and are difficult to cut. This difficulty can be very greatly decreased by the use of pea guards on the mowing machine sickle bar. These raise the peas up so they are cut off squarely. Where stacked it is necessary to rake or at least cock the peas for curing.

Harvesting should be done at a time when the greatest quantity of peas may be saved. There are always some pods which ripen later than others and cutting should take place at a time when the greatest possible number of developed pods may be obtained. The peas and grain mature to the proper stage for cutting at practically the same time.

When put into the silo peas are allowed to mature to about the same stage, cut, raked, and taken immediately to the silo. Even then, it is often necessary to run some water in with the peas to make them keep successfully.

WHEAT.

Wheat as a crop has a place on practically every farm in the Valley, as it fits in well with rotation and will make a feed or cash crop almost every year. It has been amply shown, however, by past experience in the Valley that wheat should not be grown as an entire crop. In some sections wheat has done exceedingly well, and was planted extensively and often the entire acreage of not only one farm, but of hundreds of farms, was planted exclusively to it. Naturally under such management the soil productivity declined. Wheat cannot be grown continuously on any soil in any climate. Without a rotation of some sort disaster will arrive sooner or later. However, as a crop occupying part of the farm acreage and a place in the rotation, wheat has a great value.

Winter Wheat.—Winter wheat has not been grown extensively in the Valley. It might be utilized to a greater extent. The only varieties worth considering at present are those belonging to the Turkey type, Turkey Red and Kharkov being the best. Land for winter wheat should preferably be plowed in July or early August. Plowing should be deep. Frequently it would be advisable to follow the plow with a disk harrow. Seeding should be done the last half of August, while successful plantings and successful crops are often made with much later seeding; but the practice is not advisable in the length of season which prevails, as it will result in failure many times when earlier planting will be successful.

Seeding should be done with a drill, preferably and on most lands with a disk press drill, using sixty pounds of seed per acre.

On very heavy lands it is sometimes not advisable to use the press wheels, but cover with chains or other devices. Under other conditions the press drill is to be preferred.

Spring Wheat.—Practically all of the spring wheat grown has been Defiance. The famous Marquis wheat has been tested. This variety matures in a season from ten days to two weeks earlier than Defiance and has a better quality of grain, but under good cultural conditions does not yield nearly so heavy a crop, consequently, for most conditions Defiance is the preferred variety.

Spring wheat should follow peas, or cultivated crop in the rotation. Where the soil moisture is such as to permit fall plowing without undue blowing by winds during the winters the land should be fall plowed so that early spring seeding may be done. Seeding should take place quite early in the spring, in March and April, if possible, injury by early frosts being little to be feared.

Preparation of Soil.—Land for wheat should be plowed rather deeply a considerable time previous to planting. Fall plowing accomplishes this for spring wheat, altho following dry winters land fall plowed may be rather dry for seeding in the spring. This is really the only objection that can be offered where winds do not need to be considered with a specific soil. Prior to seeding, land should be well compacted by disking and harrowing so as to provide a firm seed bed. The preparation of land for wheat, oats, barley, spring emmer and other spring small grain crops should be much the same. Spring wheat should be seeded at the rate of about ninety pounds per acre for most irrigated conditions of the valley. If a smaller amount is used, the stand will be so thin that weeds will take partial possession; if more is used, the stand will be so thick that the grain itself will act as a weed and reduces the yield by undue competition.

In general the care of seed thruout the valley is extremely lax. Seed is often mixed with barley, oats, peas, wild peas and other impurities. More care directed to screening and grading the seed would result in much more satisfactory crops.

Irrigation.—In the spring if the ground holds moisture enough to keep wheat growing, it should not be irrigated. An irrigation should be given, however, just as soon as water is needed. In other words, the wheat should be kept growing continuously. Irrigation should stop at the blooming period and in no case should water be applied after the grain has reached the soft dough stage, except on almost pure gravel patches. Late irrigation deteriorates the quality of the grain and prevents proper ripening.

Proper surface irrigation will return heavier yields than sub-irrigation, because of the better aeration of the soil and increased root room which this method will give.

Harvesting.—Occasionally a wheat crop will be caught by early frosts so as to render it unfit for milling purposes. Under such conditions it is sometimes advisable to harvest for hay. Wheat cut in the soft dough stage and cured makes an excellent quality of very palatable, nutritious hay. When not caught by frosts wheat should be cut in the yellow ripe stage. Stacking is advisable unless thrashing out of the shock can be done within one or two weeks of harvest.

After the wheat is removed there will usually spring up many weeds, especially on the older lands. To prevent the seeding of these weeds and to preserve moisture and fertility it is well to disk the stubble and plow.

OATS.

The cool climate of the Valley is especially favorable to oat production where soils have been kept up in proper fertility. The straw, after the grain is thrashed, makes very good feed, almost as good, in fact, as a great deal of hay grown in lower altitudes.

The preparation of land for oats is much the same as for wheat. Oats should be seeded a little later in the spring than wheat as it is more liable to injury from spring frosts. It is safe to seed in April and even as late as early May if seasonable conditions warrant. The order of planting with most of these crops should be barley, wheat, emmer, oats, as oats will stand the least frost of any of the crops.

What has been said in regard to irrigation for wheat will also apply for oats.

Varieties.—The two varieties that give the greatest promise for the Valley are the Colorado Number 37 and the Kherson. Colorado Number 37 is a Swedish type. The original selection from which it was originated was made by the Colorado Experiment Station in the San Luis Valley and the variety is consequently well adapted for Valley conditions. Kherson is the earliest maturing variety grown in Colorado. It has given very good results and heavy yields of grain. The production of straw, however, is very much less than in the case of Colorado Number 37, but either of these varieties is good.

Growers should follow community growing to a considerable extent—that is, a neighborhood should grow either one or the other of these varieties in order not to have mixed seed or mixed grain. The Colorado Number 37 will probably do best on the

heavier lands. As the soils commence to get lighter Kherson will be the preferred variety. Kherson will do better at the higher altitudes.

Many other varieties of oats, such as the New Market, the Big Four, the Swedish Select, all do fairly well. It would be best, however, for valley growers to confine their selection to the Colorado Number 37 and the Kherson, the two best adapted varieties. Oats are excellent feed and also make a very high quality of hay if cut for that purpose.

Seeding.—The amount of seed to use per acre will depend somewhat upon the variety. Large plump seeds require heavier seeding than smaller ones, but about eighty pounds of seed per acre is the average amount to plant. With very large seeded Colorado Number 37, it will sometimes be advisable to sow as much as ninety pounds or even more to get proper results, because the larger sized seeds run fewer to the pound.

BARLEY.

During the past few years barley has been more or less an uncertain crop in the Valley, altho in general it has been very well adapted to the soil and climatic conditions. However, barley is easily affected by changes in soil and soil fertility, and in recent seasons very deficient barley growths have been secured. The liability of the recurrence of this trouble is the strongest objection that can be urged to barley as a feed crop, but owing to this objection barley will probably be found most valuable as a crop to plant with peas. For this purpose the so-called beardless barley is to be recommended, as the absence of beards is very desirable in feeding hay or straw to animals.

All of the bearded varieties, Hanna, Oderbrucker, and California do well and produce in normal seasons rather heavy yields of thrashed grain.

Seeding.—Barley can be seeded as early in the spring as peas without probable danger of injury from frosts. The earlier planted barley seems, in fact, to make a better growth and to be less injured by seasonal conditions than that planted later. This has been true on experimental plats near San Acacio for the past three years. Barley may be planted in late February or early March if seasonal conditions permit. When planted alone, about ninety-five pounds of seed per acre is required for all of the hulled varieties. Where the berry is exceedingly large, more pounds may be needed, and where exceedingly small a slight reduction in the amount of seed can sometimes be made profitably. With the hullless varieties less seed is required, seventy-five to eighty-five pounds being usually sufficient.

Irrigation.—Barley is more sensitive to changes in the water supply than any other of the small grain crops. A lack of water just at the proper time will always stunt the growth and irrigation should be such as to permit a vigorous continuous growth.

Harvesting.—Barley is sometimes harvested as a hay crop. When the bearded varieties are so harvested they should be cut relatively early. If they are allowed to mature until the stiff dough stage, the beard is liable to be a serious obstacle to successful feeding. The beardless varieties can be cut anywhere from the soft dough to the stiff dough stage and made into good hay.

When cut for grain they should be allowed to get to the yellow ripe or well past the stiff dough stage before cutting. Except in years of short straw growth, barley will be cut with the binder or header. When conditions are such as they were in 1913, when a very short growth of straw was produced, much barley can be harvested only with a mowing machine.

EMMER.

Experience with winter emmer in the Valley is not sufficient as yet to justify its recommendation for general planting. Difficulty seems to be encountered in getting soil conditions such as will prevent severe spring killing. With the soils dry and with windy weather in the spring, spring killing is almost a certainty. Conditions have not been sufficiently favorable to warrant recommending the crop except in favorable locations.

Spring Emmer.—Spring Emmer gives promise of being a strong rival of barley as a grain feed crop. Emmer belongs to the wheat family. The hull, however, sticks to the berry when the grain is thrashed, this peculiarity distinguishing it readily from the common wheats.

Preparation of the land and irrigation are the same as for wheat. Emmer can be seeded as early as wheat, about ninety-five pounds of seed per acre being used. It may have some value as a hay crop in occasional years, but if grown at all it should be for a grain feed.

RYE.

Winter rye gives promise of being valuable as a feed crop both for the straw and grain. It should be planted on land prepared the same as for wheat and at about the same time. From 60 to 70 pounds of seed per acre should be used. Irrigation should be about the same as for winter wheat. The larger proportion of the small grains production in San Luis Valley is for feed. Except to raise seed and to have a grain feed to be used separately, the most of the

plantings may well be in pea-grain mixtures, to which reference has already been made.

SUGAR BEETS.

Sugar beets have been declared a failure for the San Luis Valley. The factory built at Monte Vista and operated for a short time is now idle, partly because of financial conditions, but largely because of the inability of the factory to get beets. The sugar beet crop must be looked upon and treated as a garden crop if successful and profitable yields are to be produced. There is no fundamental reason why beets should not do well in the Valley, but to produce them profitably it is necessary to put the soils in proper tilth and a high state of fertility. The Valley soils contain abundant mineral constituents, but for the best production the soils must also have incorporated in them organic matter in considerable amounts. With the proper incorporation of organic matter, deep and thorough plowing and proper cultivation and irrigation, sugar beets might be a successful crop, but with present methods of management the yields generally will not be heavy enough to induce growers to produce them.

Upon many farms it might be desirable to grow some sugar beets, or preferably stock beets or Swedish turnips, to help out the winter supply of succulent feed. Sugar beets, stock beets and stock turnips all do well on land properly prepared and cultivated. Until a larger proportion of the community is willing to adopt the methods necessary, these crops should be planted in very small acreages, as they are expensive of time and labor.

POTATOES.

In the past potatoes have been considered an excellent crop for the Valley conditions. Some world's record potato yields have been produced. In the past few years, however, blight and other diseases not yet understood have made yields very uncertain. Potatoes make a very poor crop for new lands. When grown at all they should be planted on lands which have been under cultivation for some time—preferably lands which have produced several crops of peas or been in alfalfa or sweet clover.

Potatoes as a market crop are only adapted to the more sandy lands. On such soils as have had their fertility built up by proper rotation of peas, alfalfa or sweet clover, potatoes are still a good crop when prices are good and diseases absent. Whether or not they should be grown is a question for each farmer to settle for himself because of the general uncertainties of production and marketing. Owing to the short season, potatoes should be planted early, preferably early in May. Under Valley conditions, whole

seed should be used. The varieties which are best adapted to conditions are not always the best market varieties, but the Pearl, the Charles Downing, and the Irish Cobler, are among the best varieties.

Potatoes should never be irrigated by sub-irrigation methods, because such soil treatment tends to increase the ravages of potato diseases. Land for potatoes should be in a high state of fertility and deeply plowed. Irrigation should be by the furrow method after the potatoes have been ridged. Small streams of water should be used and great care taken not to over-irrigate. The Colorado Experiment Station has published complete bulletins on potato culture which can be obtained when more detailed information is desired.

FLAX.

Flax does remarkably well on the soils and under the climate of the Valley, but existing freight rates render it inadvisable to grow the crop with the expectation of selling the seed in outside markets as prices are not usually high enough to cover the necessary freight charges and leave a profit to the grower. Flax is an excellent crop to use sometimes as a supplementary feed for livestock. For dairy and pure bred herds especially, a small amount of ground flax added to the rations will give tone and quality to the animals. For such purposes it is sometimes advisable to grow flax. For a cash crop prices usually make it unprofitable.

Land for flax should be prepared as for the small grains. It should be seeded very early in the spring, preferably in April, twenty to twenty-five pounds of seed being used per acre. Flax is subject to a disease known as flax wilt. To reduce the dangers of this disease to a minimum, all seed should be severely fanned to blow out all light seeds. The remaining heavy seeds should be treated with formaldehyde so as to kill all of the wilt spores adhering to the seed.

Irrigation.—Flax does not require heavy irrigation, but it should be kept growing continuously with light or moderate applications of water. The last irrigation should be given not later than the beginning of the blooming period. Late applications of water tend to keep the crop green, thus preventing proper filling and maturing of the seed.

Harvesting.—Flax may be harvested with a binder in the same manner as small grain. The bundles should then either be shocked or allowed to dry until cured. In many seasons flax can be harvested best with a self-rake or an ordinary mower having bunching attachments. When the straw is thoroly dry, it may be stacked or thrashed with a common grain thrasher.

SWEET CLOVER.

Sweet clover has usually been looked upon as a noxious weed. Stockmen and farmers are finding, however, that under proper conditions it is capable of making nutritious pasture or valuable hay. During the past three years the acreage in sweet clover has been greatly extended thruout the Valley, the discovery that it was valuable for feed coupled with the fact that the crop would grow on many of the alkali or partially seeped lands which would not produce other crops, has assisted in its wide distribution.

The two varieties of sweet clover are distinguished by their yellow and white flowers. For Valley conditions the yellow flowered variety is to be preferred because it is the earlier maturing, and will produce good crops of seed as well as hay. Sweet clover seed is almost exactly the same size and very similar in shape to alfalfa seed.

Land for sweet clover should be prepared the same as for alfalfa. The seeding can preferably be done in the spring by exactly the same methods as those used for alfalfa seeding. Eight to fifteen pounds of the hulled seed is sufficient. If the unhulled seed is used, twenty to twenty-five pounds must be planted to produce approximately the same stands.

Irrigation should be the same as for alfalfa. When intended for hay, sweet clover should be cut before the stems have become unduly woody. To accomplish this it is usually wise to cut when the crown shoots for the next crop appear. The first cutting after seeding should be made with the cutter bar of the mower set rather high, and may be begun when the first bloom appears. It is usually unsafe to cut earlier than this, as earlier cutting may result in killing the crop and necessitate reseeding. Methods of hay-making are the same as for alfalfa.

Probably no crop will prove more beneficial as a soil improver than sweet clover. In the short seasons of the Valley it is probably destined to considerably wider use than it now enjoys, both for hay and for pasture.

RODENTS.

Rodents such as prairie dogs and kangaroo rats do an enormous amount of damage to new lands as well as old lands which have uncultivated sections lying adjacent. The damage is two-fold. Prairie dogs and kangaroo rats dig deep holes in the fields, increasing the difficulties of irrigation and sometimes starting very severe soil washing. Unless their numbers are kept down they are also very destructive to crops. In some places it is almost impossible to start any of the garden crops or alfalfa because of the depredations

of these rodents. Frequently they will cut off the roots a few inches below the surface of growing alfalfa, thus killing the crop out so that it has to be reseeded.

These rodents can be destroyed if sufficient effort be made, or with less effort they can be so reduced in numbers that injurious effects from their activities will be relatively light. Probably poisoning is the cheapest means for disposing of them. To be effective, the poisoning must be done in the spring before green growth starts, as the prairie dogs and kangaroo rats will eat poisoned grain at this time, but will not touch it after green things become abundant. The State Entomologist and his assistant have worked out successful methods of poisoning these rodents, and will furnish methods of making up the poison upon request. Poisoned wheat will be sold at practically the cost of preparing it.

A recently devised method of killing off these small animals is by the use of dynamite. When this method is used, a piece of dynamite about an inch long is attached to a fuse long enough to let the dynamite well down into the hole. The dynamite is then lowered into the hole and earth is securely patted around the fuse so as to hold it firmly and stop up the hole at the same time. The fuse is then lighted. The dynamite burns without explosion, giving off poisonous gases which quite effectually kill any animals in the burrow. Most of the dynamite salesmen will supply printed directions for this method of exterminating rodents.

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INSECTS AND INSECTICIDES

Being a Revised Edition of Bulletin 114

— BY —

C. P. GILLETTE and GEO. M. LIST



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INSECTS AND INSECTICIDES

By C. P. GILLETTE and GEO. M. LIST

INTRODUCTION

The purpose of this bulletin is to furnish brief information regarding the insects that are most frequently found doing destructive work on small fruits, orchards, shade trees and shrubs of this State.

The aim has been to give a concise description of the insects and the treatments that have been found to be most successful in controlling them. The arrangement is not according to the scientific classification of the insects, but according to their host plants.

Part Two, on The Preparation and Use of Insecticides has been made as brief as possible and only the formulae that are in accordance with the best practice are given. Throughout the first part, the insecticides are referred to by number, for sake of brevity.

If you are in doubt as to the pest that is annoying you, feel free to write the Experiment Station and send specimens for identification. Place the insects in a box, along with some of their food, and then write us what information you can as to their work and habits.

PART I.

INSECTS INJURIOUS TO TREES, SHRUBS AND SMALL FRUITS.

APPLE AND PEAR

FRUIT

Codling Moth.—This insect probably does more damage to the apples and pears of the State than all other insects combined. Most orchard men are very familiar with the flesh-colored larva that eats into the apple and causes the wormy fruit, but few are familiar with the moth that lays the egg from which this larva hatches. It is a small grayish-brown moth resembling the color of the apple bark and has a wing expansion of from one-half to three-fourths of an inch. It flies mostly in the twilight and is not attracted by light. It flies with a zig-zag motion and does not remain long on the wing.

The larvae pass the winter in tough silken cocoons under the rough bark, in crotches of the trees, in cellars and packing houses, in fruit boxes, and in rubbish on the ground. The moths begin to emerge as the blossoms fall from the trees, and soon begin to lay their eggs upon the upper surface of the leaves near the small fruit. Later in the season, when the fruit is larger and the fuzz has been rubbed off, many eggs are placed directly upon the fruit. Our records show that about 65 percent of the little larvae of the first

brood, and 40 to 50 percent of the second enter the calyx as soon as they hatch from the eggs. The larvae feed in the fruit for about 21 days, then crawl down the tree to hide while they pupate and change to moths. There are two broods a year in Colorado. It takes about 50 days for one complete generation to develop from egg to egg or moth to moth. See Plate 1.

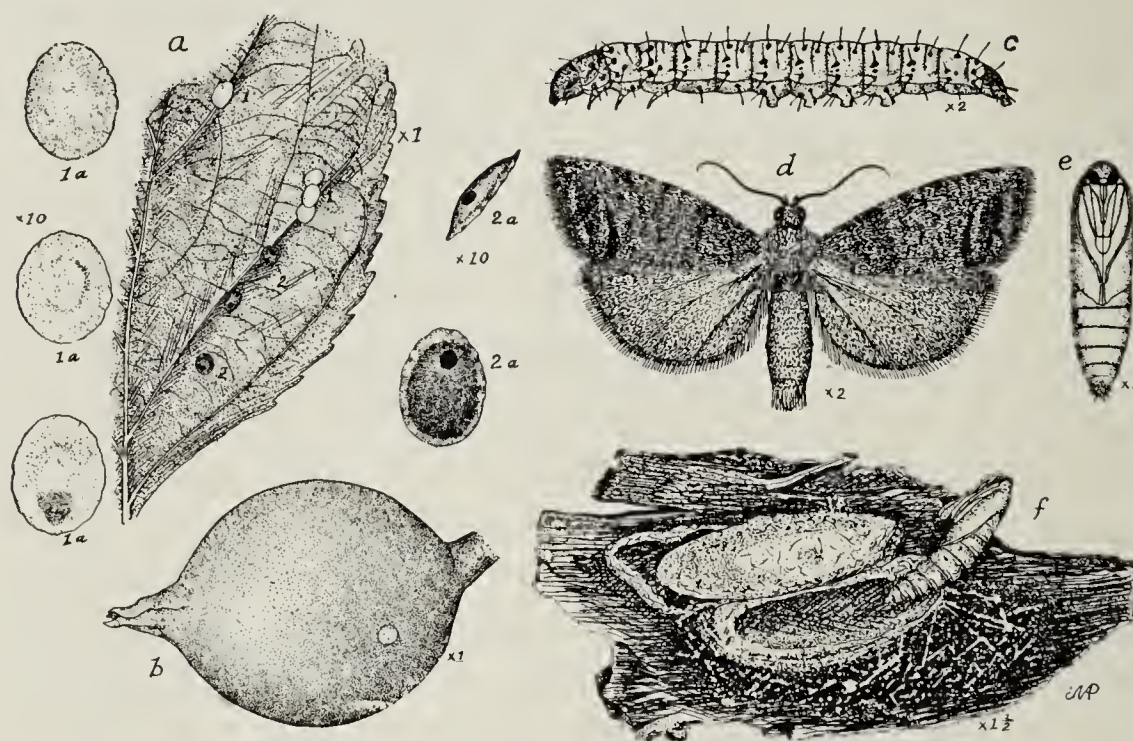


PLATE 1.—Codling Moth in its different stages: a, eggs upon a leaf; a 1, eggs natural size, 1 a, eggs much enlarged; upper 1 a, a newly laid egg; middle 1 a, the appearance of the egg after 4 or 5 days showing the flesh-colored ring of the embryo; lower 1 a, showing the outline of the small larva, the dark spot being the head (an egg in this stage would hatch in a day or two); a 2, eggs parasitized by *Trichogramma minutus*, a very small 4-winged fly that deposits its eggs within those of the codling moth; 2,a, parasitized codling moth eggs much enlarged, showing holes made by the parasites as they leave the eggs; upper 2 a, side view of parasitized egg; b, egg natural size upon an apple; c, codling moth larva; d, codling moth; e, chrysalis or pupa; f, cocoon and chrysalis. Figures a1 and a2 and b, natural size; 1 a and 2 a, enlarged 10 times; c, d, and e, enlarged 2 times; f, enlarged $1\frac{1}{2}$ times, Original, Miriam A. Palmer, Delineator.

Remedies.—Remedies 2, 4, 5, and 29 are used against this pest. The arsenical poisons are most effective, and of these arsenate of lead is most generally used, in the proportion of 3 to 4 pounds of the paste to each 100 gallons of water. As a large percent of the little worms enter the calyx of the fruit, it will readily be seen that careful attention should be given toward destroying these. The sole purpose of the first spray is to get poison into the calyx cups that these little worms will be poisoned as they try to enter the apple. This spray should be applied just after the blossoms fall, and before the calyx lobes close. There are only a few days when the fruit is in the proper condition to receive this spray. Continue the application until every calyx is filled with the liquid. Large trees will require from 8 to 16 gallons for a thorough treatment. See Figs. 1 and 2.

Much has been written in regard to the so-called one-spray method of controlling the codling moth. It consists in putting on this first spray very thoroughly. This seems to be sufficient in



Fig. 1.—a, small apple from which the petals have just fallen. Effective spraying for the codling moth may be done in this stage but it is not in as good condition for receiving the spray as b; b, small apple in the proper condition to receive the first spray for codling moth. The calyx-lobes have begun to close and form somewhat of a cup for holding the liquid and the stamens have begun to dry and will allow the liquid to enter the inner part of the calyx cup; c, cross section of b, showing the calyx cup, all parts of which must be covered with the spray to effectively poison the worms; d, pear in condition to receive the spray. Original. Miriam A. Palmer, Delineator.

some sections of the country, but in most parts of this State, where the second brood is several times as large as the first, it will usually bring disappointing results. By this method, it is possible to poison the 65 percent that enter the calyx, but it gives little or no protection against the remaining 35 percent that enter the side of the fruit.



Fig. 2.—Blossoms from which the petals have fallen and still in good condition to receive the spray. The calyxes of the two larger ones have closed. It is too late to effectively apply the calyx spray to them.

The second spray should be applied as soon as the eggs begin to hatch, and the larvae to enter the fruit. This will be about three weeks after the first spray is applied. The hatching of the first brood eggs continues over a considerable period of time, and most growers find that it pays to direct still another application against them. This should follow about two weeks after the other spray.

If the orchard has been badly infested, or is near one that is badly infested, it will pay to spray for the second brood. If a second brood spray is applied, it should follow about nine weeks after the first. If the worms are numerous, another treatment may be made in two weeks. All sprays after the first are to cover the surface of the fruit with poison.

Remedy No. 29, that of using bands, is a great help in keeping this pest under control.

Fruit-Tree Leaf Roller.—This pest often blemishes and even destroys much fruit early in the season. The little larvae begin to feed freely about the time the apples begin to form. Entire clusters of fruit may be destroyed then, or be so blemished that they will be of no value. See Plate 2.

For remedies, see under Foliage.

Green Fruit Worm.—This is a large green caterpillar with a narrow cream-colored stripe down the middle of the back, and a wide but less distinct line down each side. When fully grown, the larvae are from one to one and a half inches long. There is but one brood in a season. The moths appear in the spring and lay their eggs upon the fruit trees. The larvae hatch out and feed upon the leaves and fruit. The blemished fruit will often remain on the tree until picking time, but will show the scars. This worm feeds upon most of the tree fruits, but is most often found on the apple and pear. It feeds during May and early June.

Remedies.—The fruit worm very seldom gets numerous enough to demand attention. Spraying for the codling moth aids in keeping it in check. Any of the arsenicals will be found effective if applied while the larva is small.

Plum Curculio.—The plum curculio often does serious damage to apples, and will attack pears, but is not as serious on these as on stone fruits. The damage comes from the feeding and egg-laying punctures. This insect has never been reported in Colorado. For description and remedies see under Plum.

Apple Curculio.—This is very similar to the plum curculio and is often taken for it. It is a reddish brown snout-beetle about one-quarter inch in length with a snout or beak one-half as long as the body. It

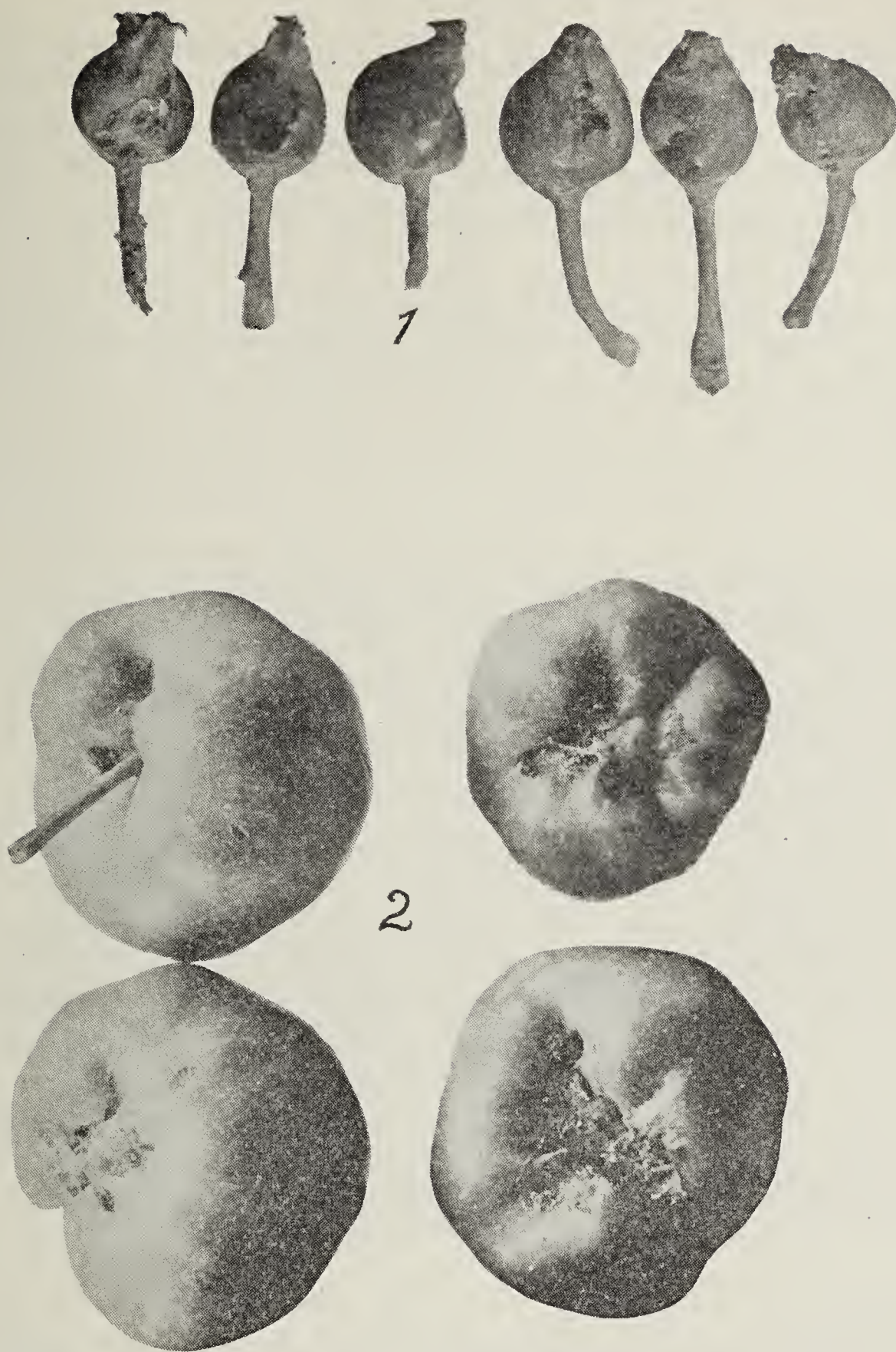


PLATE 2.

Fig. 1.—Apples picked on June 8, when they were from five-eighths to three-quarters of an inch in diameter, showing the characteristic injury from leaf-roller; figure 2, apples picked from same orchard on August 9, when they were about two inches in diameter. Original in Circular 5, Office of State Entomologist.

can be distinguished from the plum curculio by being smaller and having two humps on each wing cover, while the plum curculio has only one. The beetles hibernate under grass, or any rubbish about the orchard, and appear on the trees about the time the petals fall, and begin to feed upon the young apples. The females begin laying eggs in the apples when the later are about one-quarter inch in diameter. A puncture is made with the beak, the pulp eaten out and the egg de-

posited in the cavity. The food punctures are similar to those made by the plum curculio. The cells about the punctures are destroyed, the growth stops and a deformed apple is the result. The female seals the egg punctures with excrement and does not cut a crescent-shaped mark about them, as does the plum curculio. There is but one brood a season.

Spraying with arsenicals will destroy a few of the curculios, but best results are obtained by destroying all hibernating places and cultivating the soil. They are always worse in thick, unpruned and uncultivated orchards.

San Jose Scale.—If an apple or pear tree is infested with this pest the fruit is very likely to show scarlet blotches about one-eighth of an inch in diameter, in the center of each of which will be found one of

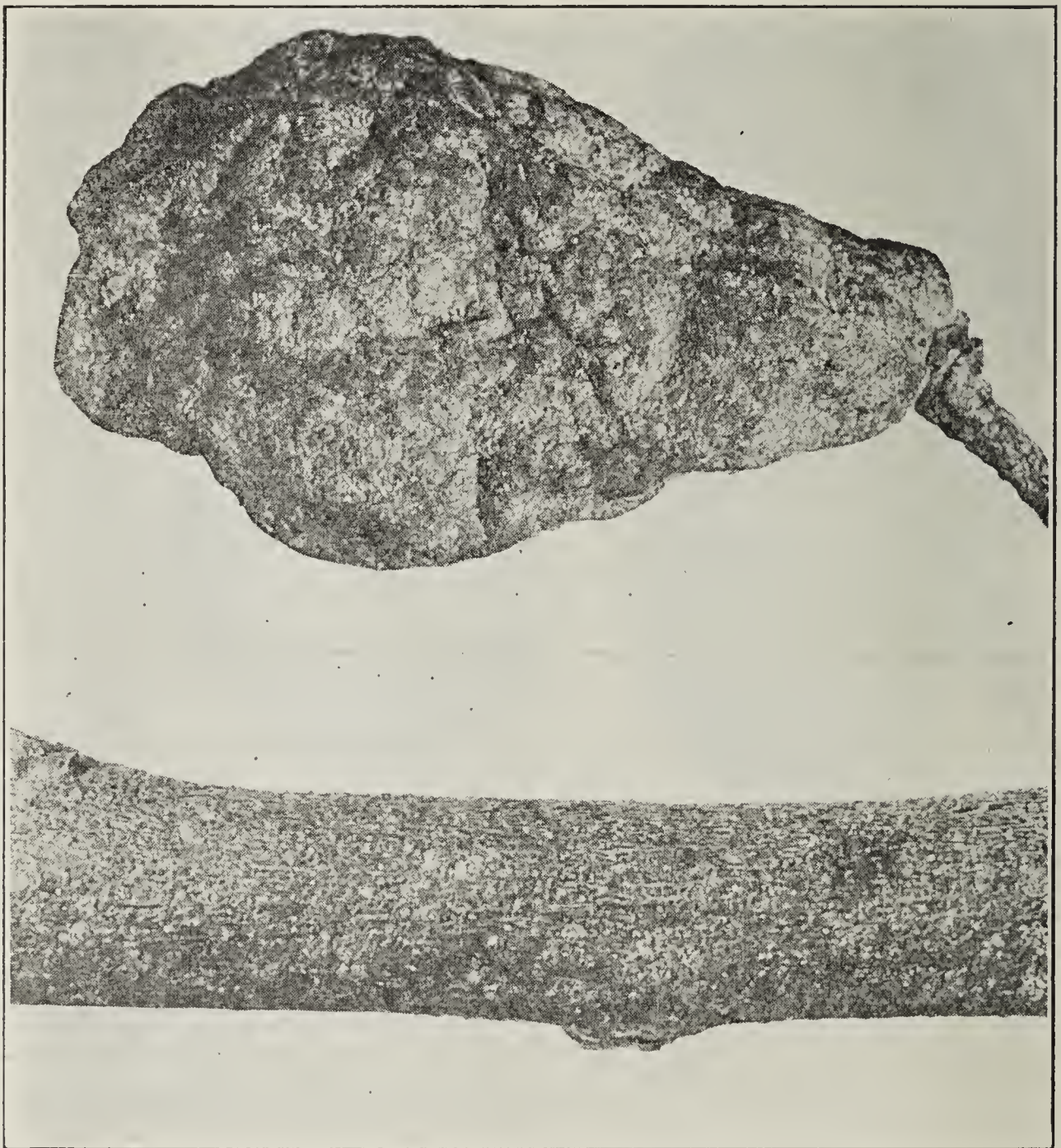


Fig. 3.—The San Jose scale on pear and willow. Note the roughened surface of the pear. Natural size. (After O. E. Essig, "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.

the scale insects. This is one of the best means of detecting an infestation in an orchard. On pears it will make more or less of a depression, but without the scarlet color being so pronounced. For remedies see under Bark and Wood. See Figs. 3 and 4.

Putnam Scale.—This is occasionally found on fruit. See under Bark and Wood.

Howard Scale.—The Howard scale quite often attacks apples and pears. It is often difficult to distinguish this from the San Jose scale. The scarlet color on the fruit shows to some extent but is not as characteristic as with the San Jose scale. On pears the depressions under the scales are usually well marked. See Plate 3. See Bark and Wood for remedies.

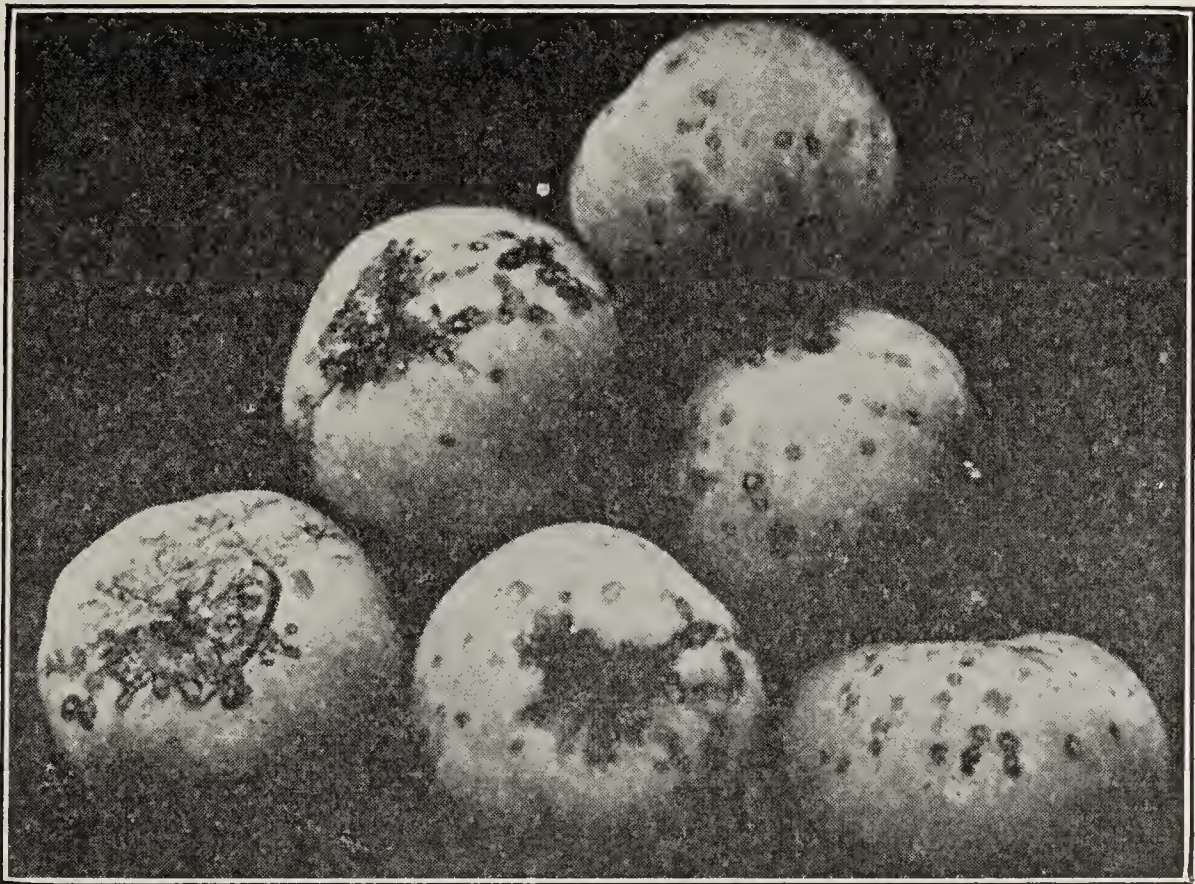


Fig. 4.—San Jose Scale on apples. Note the characteristic reddish blotches around the scales. Reduced (After Britton.)

FOLIAGE

Fruit-Tree Leaf-Roller.—This has been a serious pest in one or two sections of the State where entire orchards have been largely defoliated. It feeds upon all of our fruit trees, with the exception of the peach, and upon many shade trees. It passes the winter in the egg stage. The eggs are deposited upon the twigs and the bark of the trees in masses varying from 25 to 100 or more. The female covers the eggs with an impervious gummy substance, which protects them and gives them a brown or grayish color. They begin to hatch as the buds begin to open and the little worms enter the buds and tie the leaves together with webs. As the leaves grow they roll up forming

a nest in which the caterpillars feed. The larvæ eat fruit as well as leaves if any should be enclosed within their nest. As the leaves get larger often a single leaf will be rolled to form a nest.

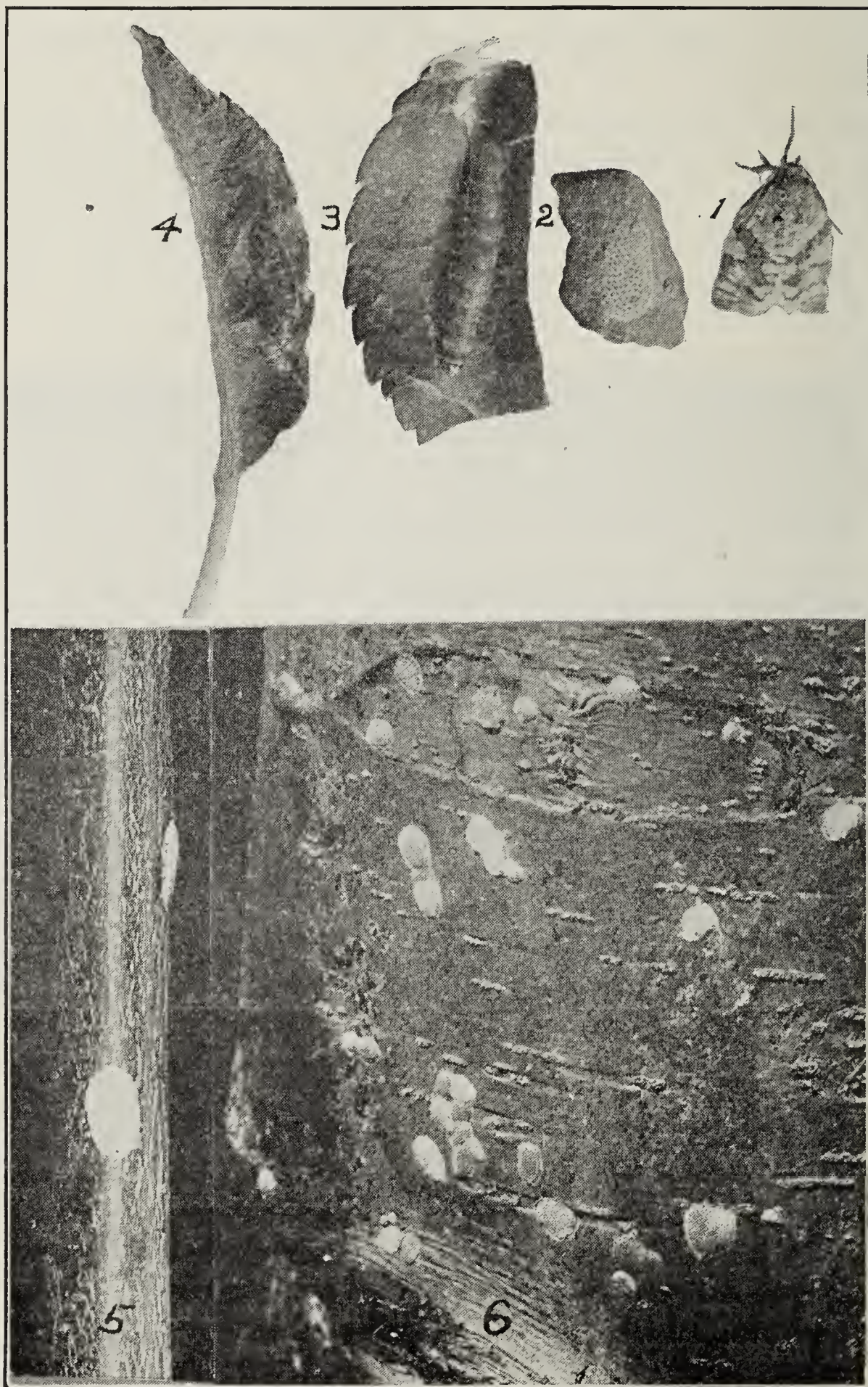


PLATE 4.— Fig. 1.—Adult leaf-roller moth; figure 2, hatched egg mass on bark; figure 3, adult larva; figure 4 pupa; figure 5, light-colored egg masses on bark; figure 6, thirty-five hatched egg masses in a space of twelve square inches. Original in Circular 5, Office of State Entomologist.

The larvæ feed for about four weeks. When mature they are light green in color, with brown or black head and legs, and they are very active if disturbed.

Pupation takes place within the nest, only a very delicate cocoon being made. The moths emerge in about ten to fourteen days and soon begin laying eggs. There is but one brood a year. See Plate 4.

Remedies.—Best results have been secured by a thorough application of miscible oil, one part in nineteen parts of water, made early in the spring before the eggs begin to hatch. Kerosene emulsion failed to give the same results.

Many of the young caterpillars can be killed by the use of arsenate of lead, 5 or 6 pounds of paste in 100 gallons of water. Make the first application just as the buds begin to burst, and the second just as the cluster buds begin to separate. The regular codling moth spray, just after the petals have fallen, should follow.

San Jose Scale.—See Bark and Wood.

Putnam Scale.—See Bark and Wood.

Tent Caterpillar.—This insects passes the winter in the egg stage and hatches as the buds begin to open. The worms make nests in the forks of branches, in which they remain when not feeding. The eggs are placed in clusters of from 100 to 200 on the small branches and are covered with a cement-like substance. See Fig. 5.

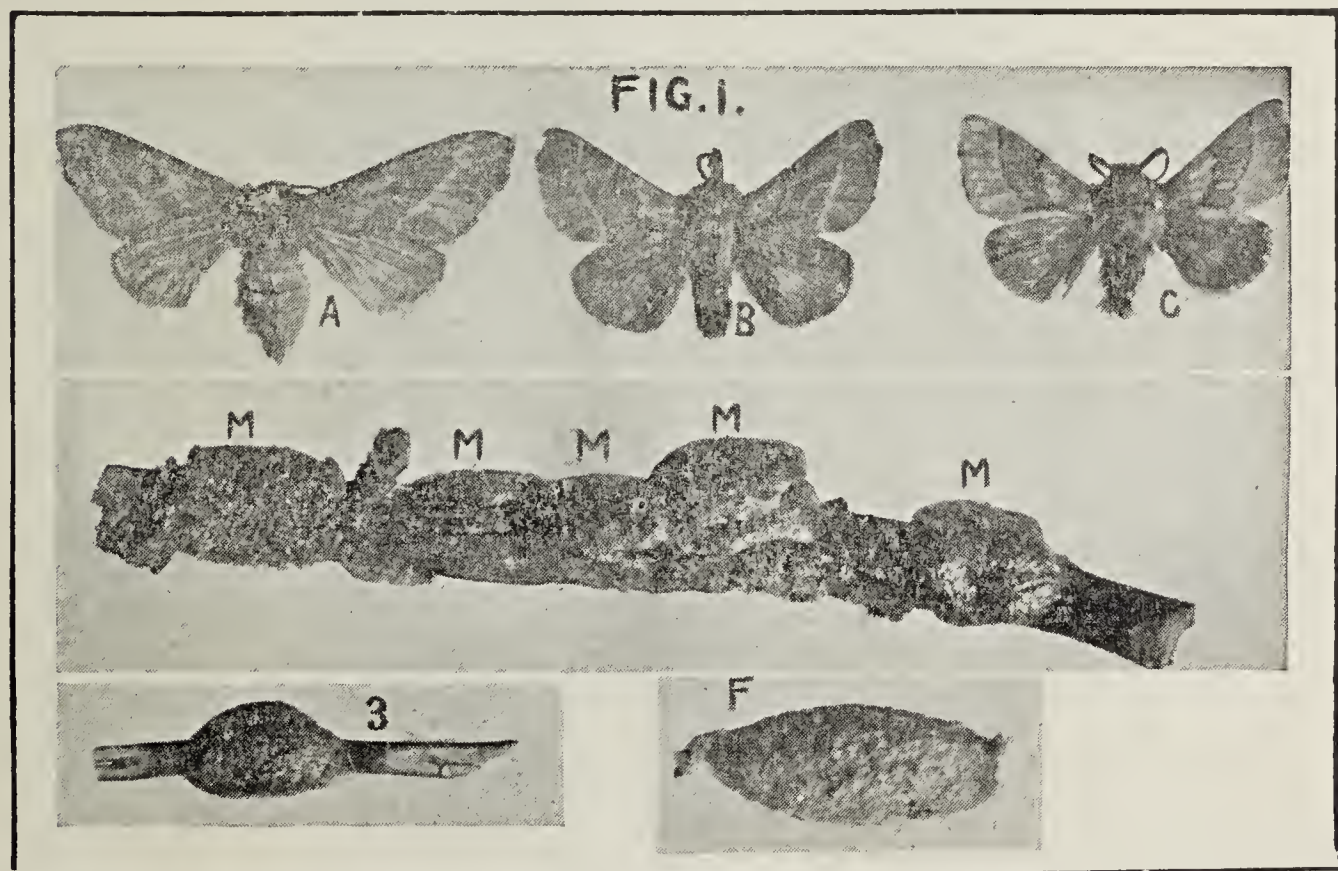


Fig. 5.—Western Tent-caterpillar; A, female moth; B, C, males; D, apple twig with egg masses (M). F, cocoon. 3, egg-mass of American Tent-caterpillar. Life size,

Remedies.—The worms are usually kept under control in orchards that are sprayed for the codling moth. Any of the arsenicals will

destroy the small caterpillars. While pruning, many of the egg masses can be cut off and destroyed. The nests can be burned out with a torch.

Fall Webworm.—The webs do not appear until late in the summer. The insect hibernates in the pupa stage. The moths, which are white, emerge in the late spring and summer when they lay their eggs upon the leaves. The worms enclose within their loose web all the foliage upon which they feed, while the Tent Caterpillar spins a smaller nest to live in when not feeding. See Fig. 6.

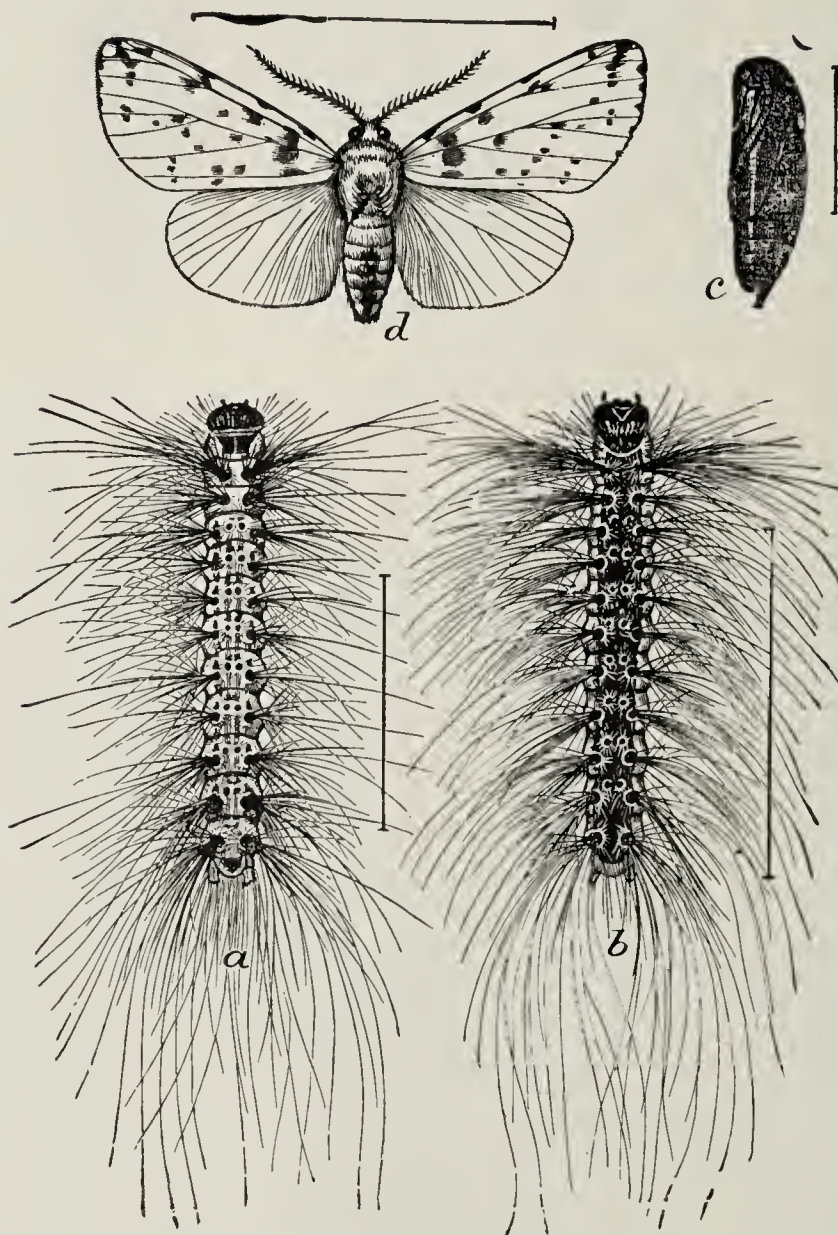


Fig 6.—Fall Web-worm; a and b, caterpillars; c, chrysalis; d, moth. (Howard, Year-book, U. S. Dept. of Agriculture, 1895.)

Remedies.—Same as for Tent Caterpillars.

Apple Flea-Beetle.—This is a small metallic-green beetle about one-sixth of an inch in length, with hind legs so developed that it can jump like a flea. These beetles sometimes attack young trees or newly budded or grafted nursery stock, and do serious damage by eating holes in the leaves. Very little damage is ever done large trees.

Remedies.—Any of the arsenicals (2-4-5) are quite effective in destroying this pest. Any material that will form a dust over the foli-

age has a tendency to keep these beetles from feeding. Nos. 6-7-15 and 27 may be used as repellants.

The Apple Leaf-Hopper.—This is a small, active, greenish-yellow insect about one-sixth of an inch in length that feeds upon the leaves of apple and pear, and some other plants, by sucking the juices and giving the leaves a mottled yellowish appearance, often causing them to fall prematurely. The young feed on the under side of the leaves mostly. They do not develop wings until their last moult, but are very active, running in all directions if disturbed. They winter over as eggs deposited in the bark of the small branches.

This insect as a rule does little damage, except occasionally to growing nursery stock, and sometimes it is abundant enough to damage the foliage and speck the fruit with excrement so that it is made unsightly and unsalable.

Remedies.—Must consist of contact sprays applied before the insects develop their wings. Spray from below to strike the hoppers on the under-side of the leaves. Use Nos. 8-9-10-11-12-18-19.

The Green Apple Aphis.—This is a small green louse that feeds on the under-side of the leaves of apples and sometimes the pear and quince, sucking the plant juices and causing the leaves to curl. It is usually worse during the latter part of the season. It winters over in



PLATE 3. Fig. 2.—Young Bartlett Pear, life size, showing both young and adult of Howard scale. The young scales are white.

Fig 3.—Two apple twigs showing eggs of the green apple aphid; between these twigs two needles of pine showing eggs of another species of aphid that works upon the pine. Original in Fourteenth Annual Report, Colorado Experiment Station.

the egg stage. The eggs are small, black, shiny objects placed upon the small twigs of the trees. See Plate 3.

Remedies.—It is very difficult to destroy the eggs. The sprays usually recommended for this purpose cannot be depended upon. The best treatments consist in spraying with tobacco extract (19), kerosene emulsion (10), or soap (8), after the eggs have hatched, and before the leaves begin to curl.

Rosy Apple Aphis.—This aphis or louse gets its name from its rosy or pinkish color. It is quite a serious pest to the apple in some sections, but has been found in Colorado in only two or three localities in sufficient numbers to do serious damage. The small, black, shiny eggs hatch in the spring about as the buds begin to open. The lice feed upon the leaves and twigs much as the Green Apple Aphis does, but they seem to have a poisoning effect on the twigs and fruit, leaving the twigs crooked and stunted and the fruit small and knotty. This pest remains on the apple and pear only a part of the season leaving the latter part of June for another food plant. It returns in the fall to deposit its eggs upon the apple and pear. See Fig. 7.

Remedies.—Same as for Green Apple Aphis.



Fig. 7.—Apples disfigured by the attacks of the rosy apple aphis when the fruit was young. These were picked at harvest time. Reduced one-half. After O. E. Essig, Bul. "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.

Grasshoppers.—Grasshoppers do serious damage to young orchards, especially when they are sown to some crop that will not permit of an

annual cultivation to destroy the eggs, or when the orchard is adjoining an alfalfa or grass field. They can be held in check somewhat by the arsenical sprays (2-4-5). The best results in poisoning them are secured with poison bran-mash (3). A band of sticky material (31) about the trees will keep the wingless ones from climbing. See Fig. 8.

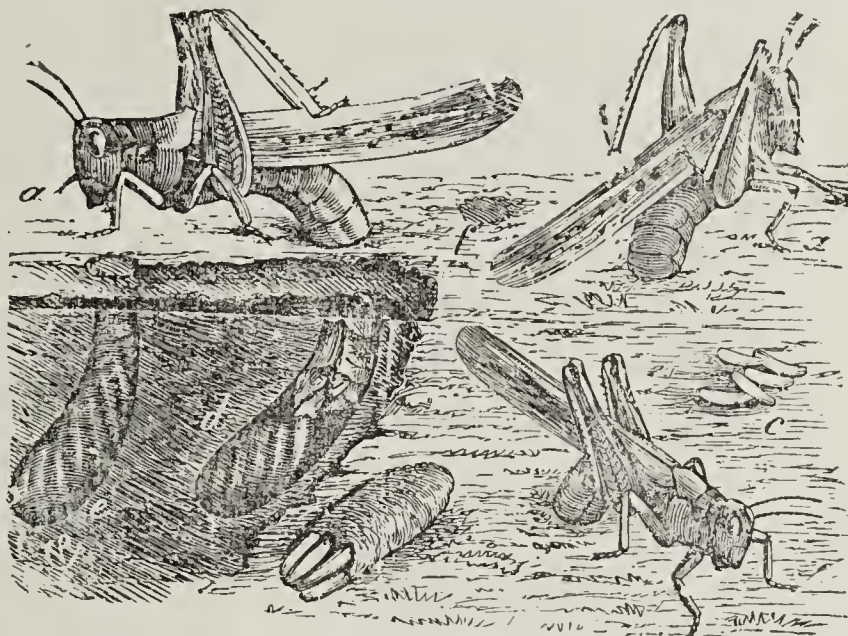


Fig. 8.—Rocky Mountain Locust, laying eggs in the ground; a, a, females with their abdomens in the ground; b, an egg-pod broken open; c, scattered eggs; d, egg-packet in the ground. (After Riley.)

The hoppers can be kept from migrating from alfalfa and grass fields by the free use of hopper-dozers or pans (30). See Plate 5.

Brown Mite or Clover Mite.—This is a very small brown or reddish mite. It feeds upon a large range of plants, including practically all of our fruits. It takes the name of Clover Mite from the clovers on which it is often very numerous. The dry climate of Colorado is very favorable to its increase. It feeds chiefly upon the leaves. Its presence is most easily detected by the faded, sickly appearance of the foliage of the trees. See Plate 6.

This pest winters over in both the egg and the adult stages, the small red eggs being placed upon the bark of the trunk and limbs and especially in the crotches of the smaller limbs. When very abundant the eggs color the bark red. Sometimes in the fall this mite becomes an annoyance by leaving the food plants and entering our dwellings. It does not bite people.

Remedies.—The use of lime and sulphur (16-17) early in the spring to destroy the eggs or the mites as they hatch is probably the best means of control. Kerosene emulsion (10) and Soluble Oil (12) are also quite effective at this time.

To kill the mites during the summer, use sulphur (20) at the rate of one pound to three gallons of water, with a small amount of soap about two pounds, to 100 gallons. Contact sprays (8-10-12-19) will destroy the mites, but a second application is required to kill those

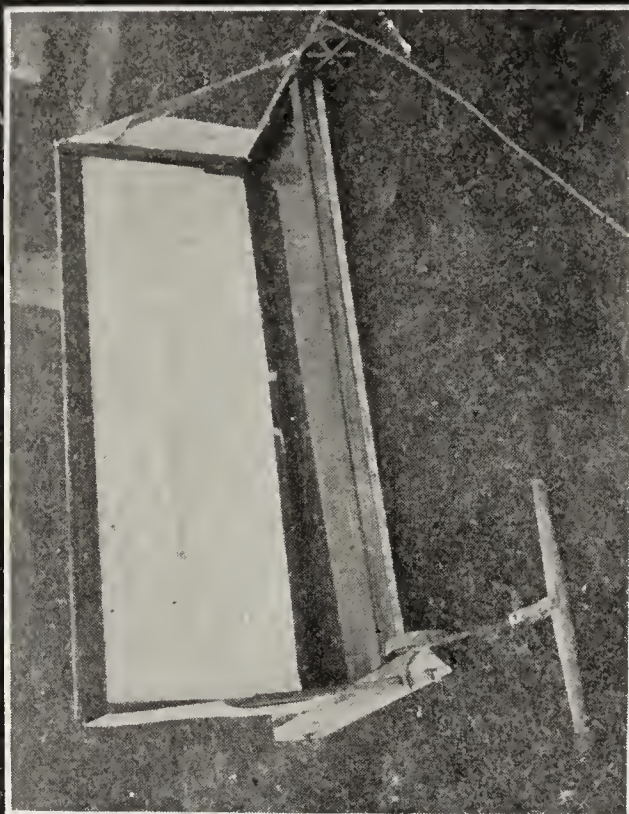
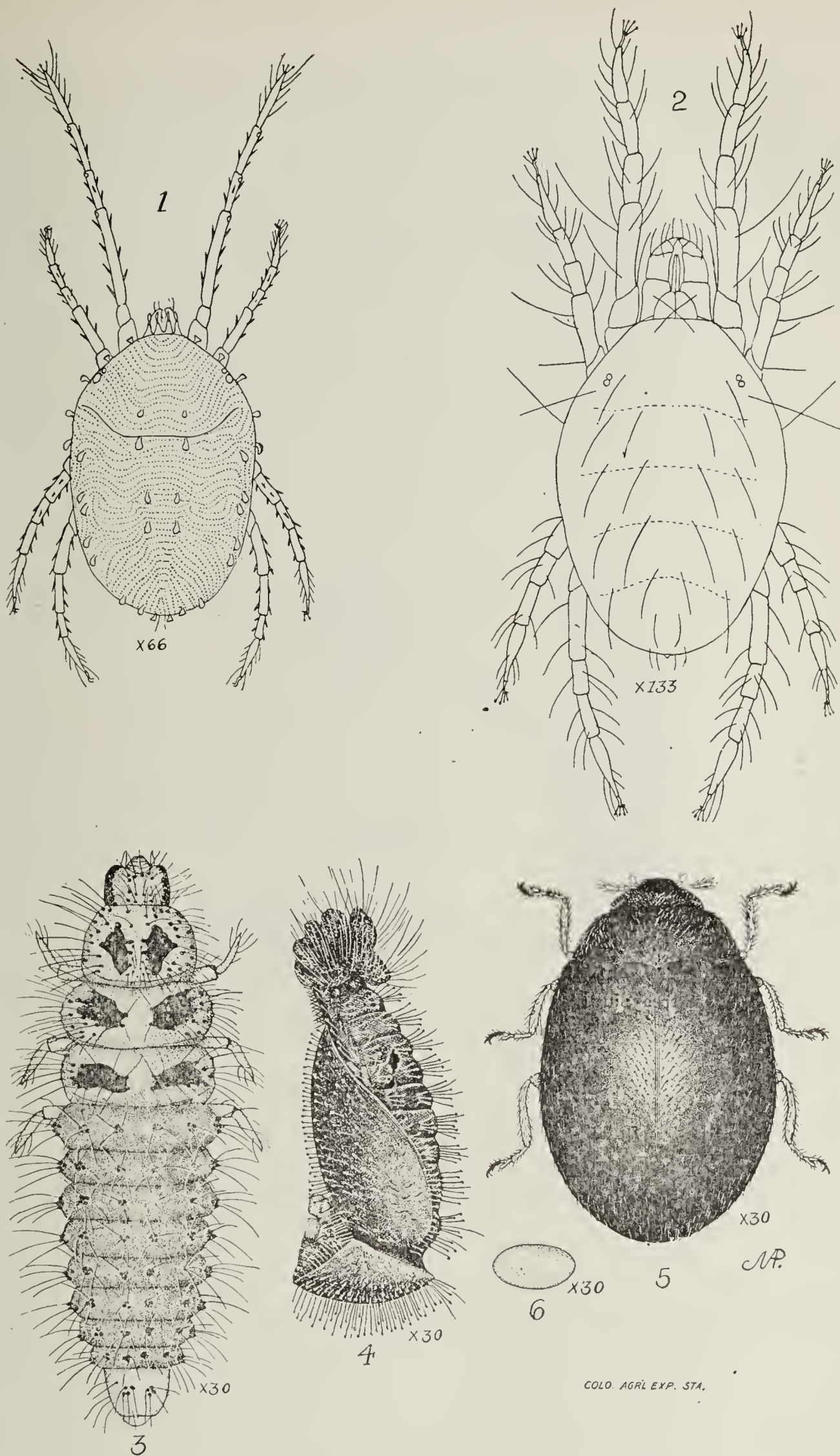


PLATE 5.—Home-made Hopper-dozer, after Blinn.
Near view, showing pan
Following the mower
Manner of hitching horse
Hopper-dozer

that hatch from eggs. Sulphur usually remains on the tree long enough to destroy any that hatch from eggs after the treatment.

The spraying should be done from below, as the mites work largely on the underside of the leaves.

The Red Spider.—The Red Spider is very similar to the brown mite, the adult being somewhat smaller and greenish or reddish in



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PLATE 6. Fig. 1.—Brown mite; 2, red spider; 3, 4, and 6, larva, pupa, adult and egg of (*Scymnus punctum*); a small lady-beetle that feeds upon the brown mite and red spider. Fig. 1 enlarged 66 times; 2 enlarged 133 times; 4, 5, and 6 enlarged 30 times. Original in Bull. 152, Colo. Exp. Sta.

color, and always works under a slight web which it spins. The work of the two are often confused, but they vary a great deal in their life histories. The young red spider winters over under the bark of trees and rubbish on the ground. The spiders are best distinguished from the brown mites by the fine web they spin over the surface of the leaves. The young resemble the adults but are lighter in color. See Plate 6.

Remedies.—The remedies recommended for summer use against the brown mite will control the spider also. In cities where a strong current of water is available, both the mites and spiders may be controlled by frequently washing them from from plants and trees.

Pear Slug.—See under Cherry.

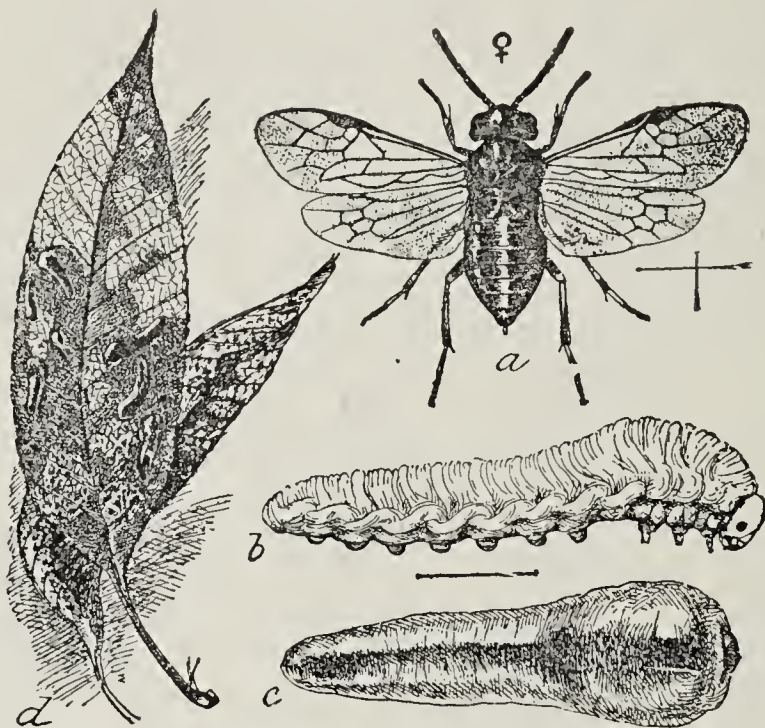


Fig. 9.—Pear-tree Slug; a, adult fly; b, larva or slug with slimy covering removed; c, same as preceding in natural condition; d, leaves showing slugs and their injuries. (Marlatt, Circular 26, Second Series, U. S. Dep. of Agr., Div. Entomology.)

Pear Leaf-Blister Mite.—This is a very small mite that lives within the tissue of pear leaves, and in some cases apple leaves, causing small reddish or brownish blisters. When numerous these may involve the greater portion of the leaves causing them to fall prematurely.

The mites pass the winter under the bud scales on the trees.

Remedies.—Spray while the trees are dormant, with lime and sulphur (16-17) kerosene emulsion (10), or Souble Oil (12).

Vagabond or Rust-Mite of the Pear.—This mite is quite similar to the preceding in size and appearance, but feeds entirely upon the surface of the leaves and tender bark of the new shoots, causing a rusty appearance and a dwarfing of the foliage. In severe cases the leaves curl and the foliage seems scanty. See Fig. 10.

Remedies.—Same as for the preceding species.

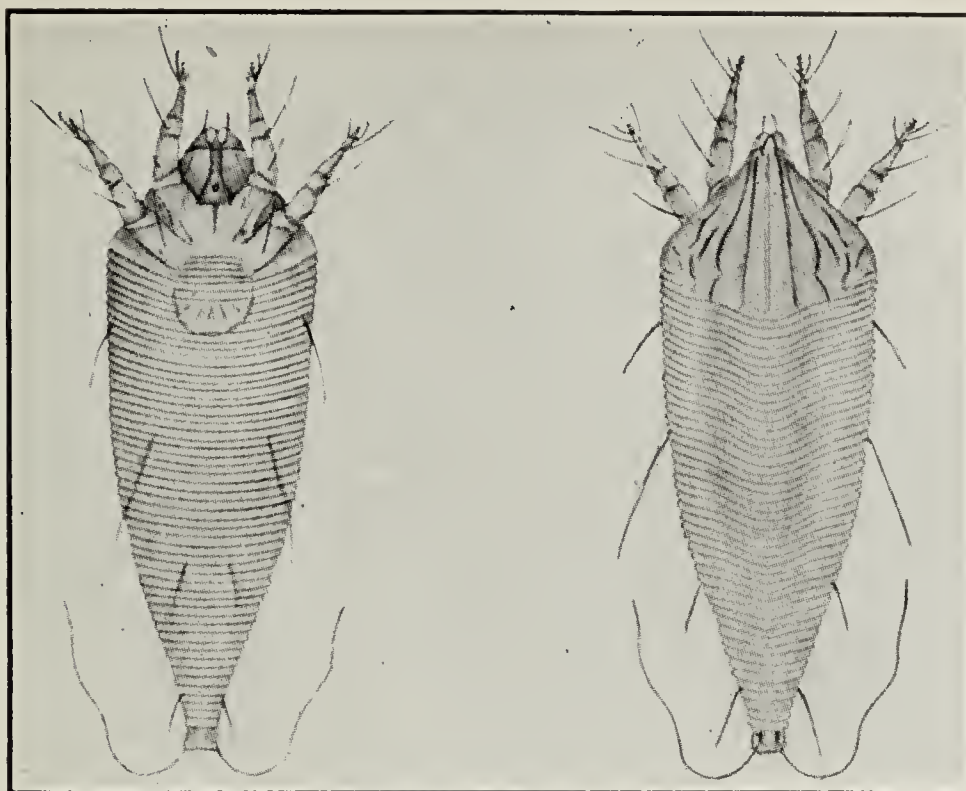


Fig. 10.—The Vagabond or Pear-leaf Rust Mite. Ventral and dorsal views. Greatly enlarged. (After Malepa from Parrott.)

BARK AND WOOD

San Jose Scale.—This is one of the most dreaded insects to all orchardists. It is responsible for the death of thousands of fruit trees in many sections of the country each year. The great danger comes from the rapidity with which it multiplies, and the difficulty the inexperienced orchardist has in locating the infestations. It may be present in sufficient numbers to kill the trees before its presence is discovered. It attacks practically all deciduous fruits and ornamental plants, infesting all parts of trees including trunk, branches, leaves and fruit, often getting so abundant on the branches as to encrust them with scales, giving them a gray, ashy, dead appearance. See Fig. 3.

The scale is a waxy secretion which, together with the old cast skins of the insect, acts as a protection to the soft yellow insect beneath it. The full grown females are covered by a circular scale about one-sixteenth of an inch in diameter with a central dark nipple. The scale of the male is smaller, gray in color, and oval, with the nipple nearer to one end.

The small, half-grown female scales are dark in color, almost black, and circular. This characteristic is used to distinguish this scale from the Putnam and Howard scales, and other closely related species.

When upon fruit the San Jose Scale makes a red or scarlet blotch that is quite characteristic. During fruit harvest is one of the best times to detect infestations. This same red discoloration is found within the outer bark surrounding the feeding place of the insect. See Figs. 3 and 4.

If trees are found to be infested, immediate action should be taken. Small trees may be killed in one or two seasons and older trees so weakened that they are of little value. This scale has been discovered in one fruit growing section of Colorado, and may break out in others at any time. Anyone finding scale insects that he can not identify should send them to the Experiment Station for identification.

Remedies.—Spray with lime and sulphur mixture (16-17) while trees are dormant. The soluble or miscible oils (12) are also quite effective. It is usually best to cut and burn badly infested trees.

Putnam Scale—This very closely resembles the preceding species. Mature scales are slightly larger and lighter in color and the central spot on the scale is reddish and somewhat to one side of the center. Remedies the same as for the preceding.

Howard Scale.—This scale is very difficult to distinguish, in external appearance, from the preceding species. It is about the same size and has a pale gray color, with a dark orange colored nipple somewhat to one side of the center.

This species is pretty generally scattered over the State. It does most damage to the pear, plum and prune, but also infests apple, peach, ash and maple. It causes a peculiar pitting of the surface of pears. It

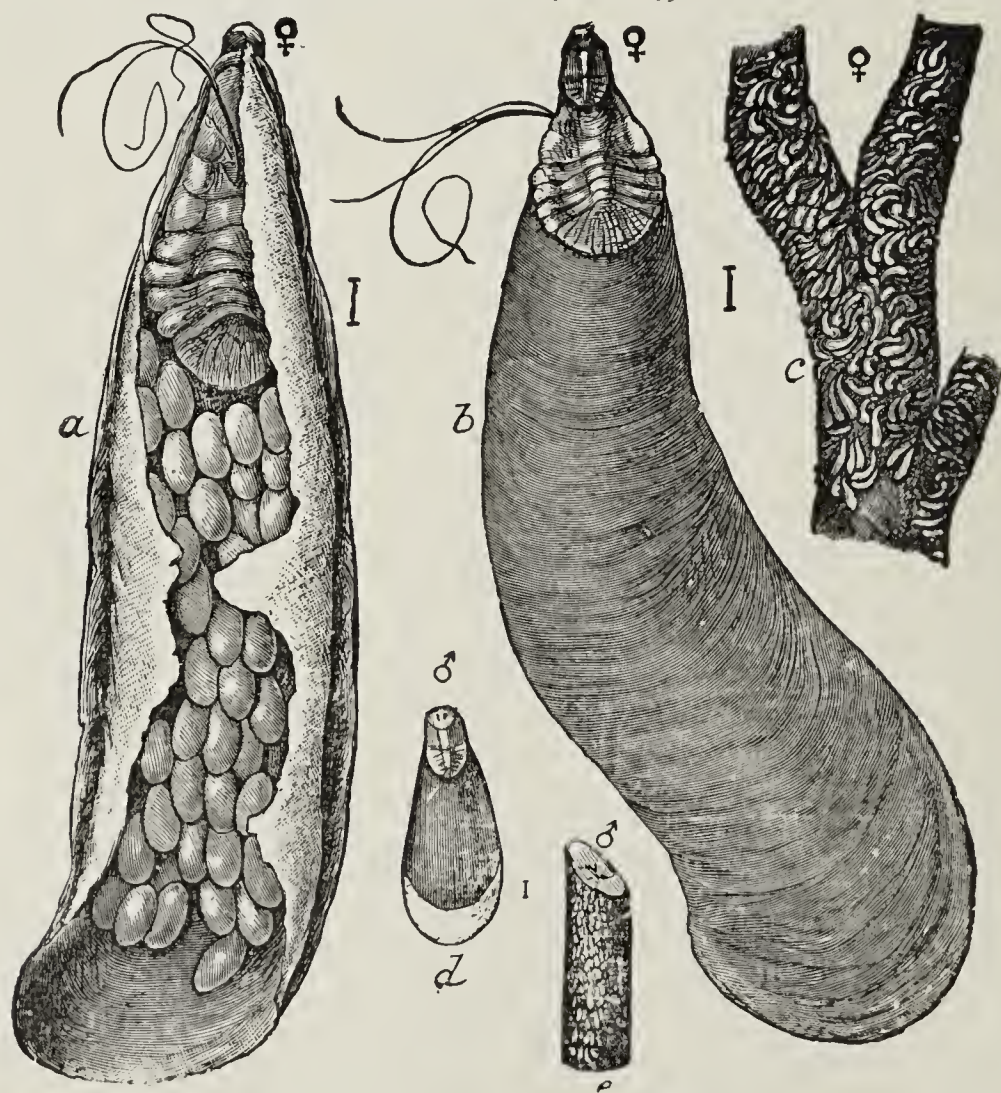


Fig. 11.—Oyster-shell Bark-louse: a, female scale from below, showing eggs, greatly enlarged; b, the same from above; c, female scale on twig, natural size; d, male scale enlarged. Howard, Yearbook, U. S. Dep. of Agr., 1894.

also makes the scarlet blotches on fruit and bark somewhat similar to the San Jose scale, but does not increase as rapidly. See Plate 3.

Remedies.—Same as for San Jose Scale.

Oyster-Shell Scale or Bark Louse.—This is an elongated oyster-shell shaped scale of about the same color as the bark of the trees. It infests especially lilac and apple and pear trees. It passes the winter in the egg stage under the old scale. See Fig. 11.

Remedies.—Dormant sprays are ineffective. Black leaf 40 (19), 1 part to 800 parts water, or kerosene emulsion (10), 8% kerosene, applied in the spring when eggs are hatching, will kill the young lice.

Scurvy Scale.—This is a white scale insect. The female is about one-eighth of an inch long, flatter and more circular than the oyster-shell scale, and gives the bark a scurvy appearance. Male scales are much smaller and very slender. Like the Oyster-shell scale, it passes the winter in the egg stage under the old scales. When eggs are crushed they are of a deep purple color.

Remedies.—Same as for Oyster-shell scale.

Woolly Aphis.—Small reddish-brown lice attacking trunk and branches of the apple, especially on tender bark about wounds and on water-sprouts. They appear as bluish-white woolly patches which, when crushed, give a dark blood-red stain. The lice are covered with a woolly mass of white secretion. They suck sap from the bark and often cause an abnormal growth or swelling where they feed. See Fig. 12.

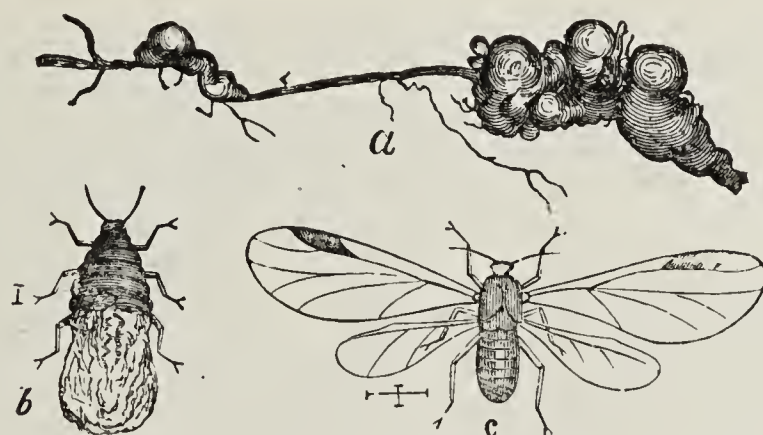


Fig. 12.—Woolly Aphis, root form: a, small root showing swellings caused by the lice; b, wingless louse showing woolly secretion; c, winged louse. (After Saunders.)

Remedies.—The white patches on the trunk and branches may be painted out with pure kerosene or crude petroleum (11), kerosene emulsion (10), or tobacco extract (19).

If the lice become abundant on branches and twigs, spray with "Black Leaf 40," 1 part to 800 parts water, with 3 pounds of soap to each 100 gallons to aid in penetrating the woolly secretion; or use kerosene emulsion (10) ordinary strength. Use a high pressure and coarse spray, in order to wet through the wool.

Flat-Headed Borer.—A light-yellow legless grub that bores beneath the bark of apple and many of our shade and forest trees. The first body segments are flattened, making the larvæ appear to have an enlarged flat head. The adult is a dark brown metallic colored beetle about three-fifths of an inch long. This insect very seldom attacks any but weakened or injured trees. See Fig. 13.

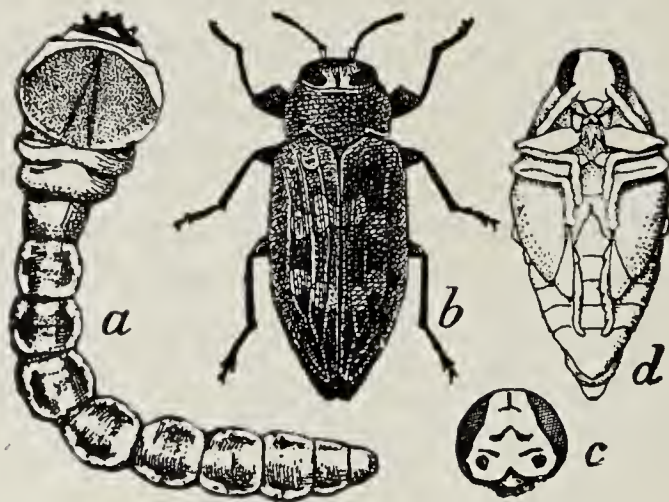


Fig. 13.—Flat headed Apple-tree Borer; a, flat-headed larvae; b, the mature beetle; c, head of mature beetle; d, pupa. All twice natural size. (Chittenden, Circular 32, U. S. Dep. of Agr., Div. of Entomology.)

Remedies.—Keep trees in thrifty condition. Protect from sun scald during winter and spring by shading or white-washing (15). Remove borers with pocket-knife when found.

Grasshoppers.—Grasshoppers sometimes eat bark from trees in the nursery rows or in young orchards.

Remedies.—See under Foliage.

PEACH, PLUM, PRUNE, APRICOT AND CHERRY

FRUIT

Twig-Borer of Peach.—The small brown larvæ of this insect winter over in silk-lined cavities made in the bark, especially in the crotches of small limbs. These are detected by a small mass of chewed bark which covers the burrows. Early in the spring the larvae leave the burrows and eat into the buds and new shoots causing them to wilt and die. The same larva may eat into several twigs, thus a few can do serious damage, especially to small trees. See Figs. 14 and 15.

Many of the second brood larvae eat into the peaches, causing a gummy exudation and ruining them for the market. This is probably the worst insect pest of the peach in Colorado at the present time.

Remedies.—Lime and sulphur mixture (16-17) has been most generally used in this State. Spray just before the buds begin to open. At this time the larvæ begin to leave their winter quarters and are most

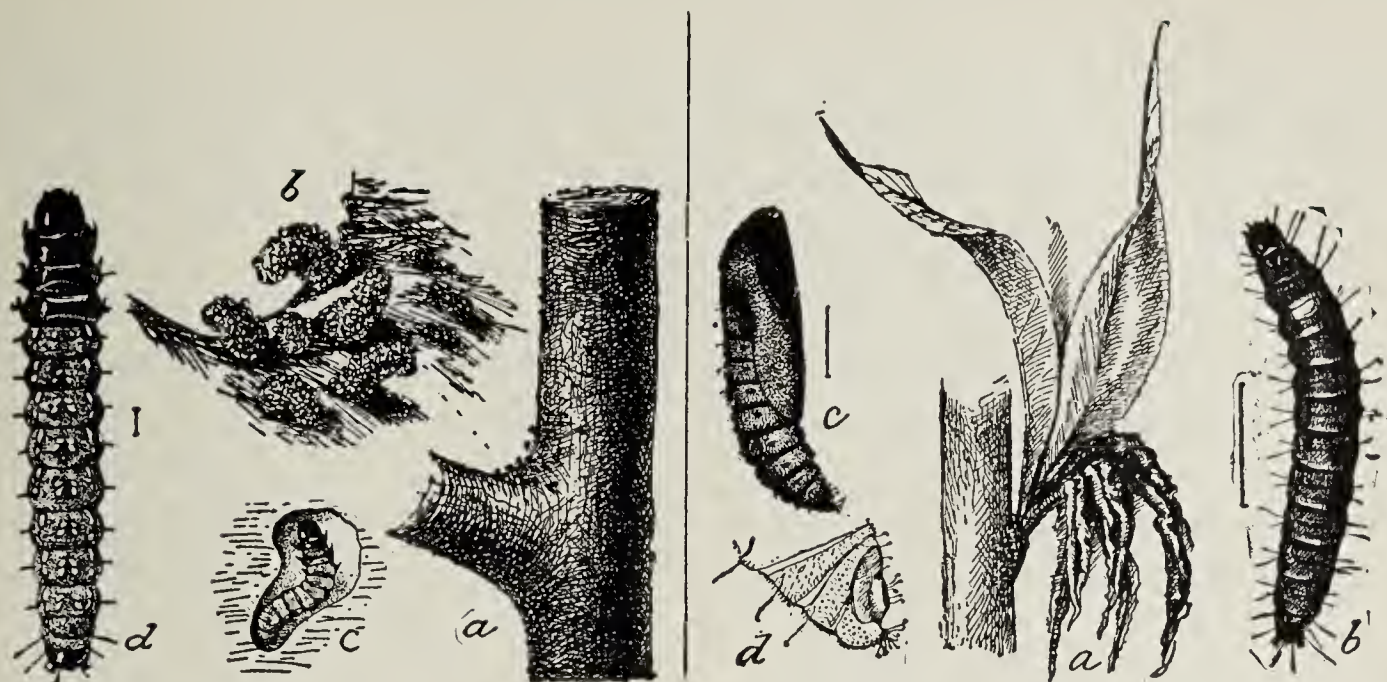


Fig. 14.—Peach Twig-borer; a, twig of peach showing little masses of chewed bark above the larval burrows; b, the same enlarged; c, larva in winter burrow, enlarged; d, hibernating larva greatly enlarged. (Marlatt, Bulletin 10, N. S. U. S. Dept. of Agr., Div. of Entomology.)

Fig. 15.—Peach Twig and Borer; a, young shoot wilting from attack of borer; b, adult larva enlarged; c, chrysalis enlarged; d, tail end of chrysalis showing hooks. (Marlatt, Bulletin 10, N. S., U. S. Dep. of Agr., Div. of Entomology.)

easily killed. Winter applications are of very little value in our experience.

Kerosene emulsion (10) and soluble oils (12) may be used, but are thought not to be quite as effective, and are more likely to cause injury.

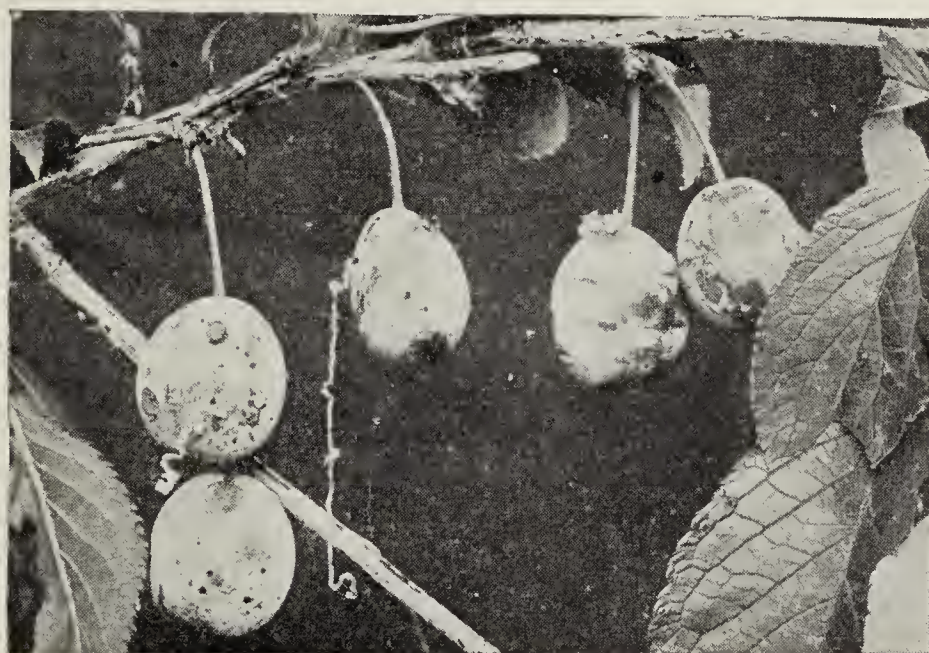


FIG. 8

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Fig. 16.—Plums, life-size, showing the punctures and gummy exudations caused by the plum gouger. The black specks on the plums represent the punctures which are made either for the purpose of taking food or egg-laying. Original in Fourteenth Annual Report Colo. Exp. Sta.

If spraying for the twig-borers alone, arsenate of lead (4) used just after the buds open, gives good results. Many growers prefer this to the lime sulphur treatment. Destroying infested fruit and twigs before the larvæ leave them aids in keeping this pest in check.

Plum Gouger.—This pest feeds upon plums, prunes and nectarines. It is a small gray snout beetle, a quarter of an inch in length, with ocher-yellow head and legs, wing covers smooth and without humps which are characteristic of many snout beetles. The beetles feed upon the fruit, making small punctures in the skin. Eggs are deposited in some of the punctures and the grub eats into the pit, destroying the seed. The larva pupates within the seed, the adult coming out about the time the fruit matures. The adults winter over in the soil. See Figs. 16 and 17.

This is probably the worst pest of the native or Americana plums in Colorado.

Remedies.—Jar the trees early in the morning and catch the beetles on sheets held beneath. Do this from the time the blossoms are out until no beetles are caught. Spray with arsenate of lead (4) soon after the blossoms fall, and again ten days later.

Plum Curculio.—This beetle is very similar to the preceeding one. It is brown to blackish in color, about one-fifth of an inch in length, and with two prominent humps and several smaller ones on its back.

There are two broods. It winters in the beetle stage in the soil, and in rubbish. The adult comes out in the spring and feeds upon the buds and foliage, and later upon the small fruit.

The food punctures in fruit are similar to those made by the preceding species, but the eggs are deposited in skin punctures that are distinctly crescent-shaped. The larvæ do not enter the pit, but feed

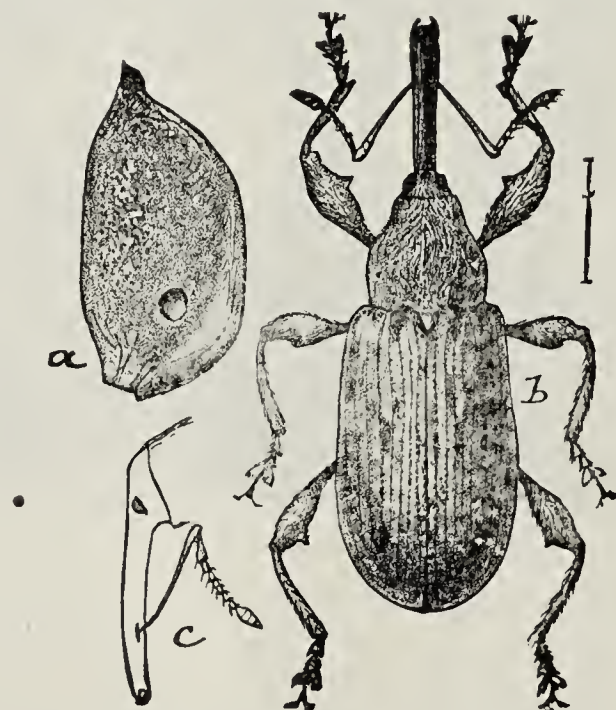


Fig. 17.—Plum Gouger: a, plum pit showing hole for exit of gouger; b, gouger; c, side view of head of gouger showing beak and antenna. (Riley & Howard, *Insect Life*, Vol. II., U. S. Dep. of Agr., Div. of Entomology.)

upon the flesh, causing the fruit to fall. The curculio infests plum, peach, cherry, apple, pear, wild plum, and hawthorn. It is to the cherry and plum what the codling-moth is to the apple.

This pest has never been reported in Colorado. Anyone finding what he thinks is its work should notify the Experiment Station.

Remedies.—Same as for preceding species. Spraying with arsenate of lead gives better results than with the plum gouger. Probably the best remedy consists in keeping the orchard free of rubbish and giving a fall cultivation to destroy the over-wintering beetles. The beetle thrives in over-grown, unpruned and neglected orchards. They are shy of the sun. Prune the trees and let the sun in.

Green Peach Aphis (See Foliage).—This plant louse attacks the fruit of the peach and plum just after the flowers fall, causing many of the little fruits to drop.

Tarnish Plant Bug.—For some time there has been considerable complaint from peach growers of the State of waxy peaches. The wax or gum forms in small beads or long strings on the fruit. When brushed off, very little, if any blemish is left. This is often caused by the food punctures of the tarnish plant bug, a small, brownish, and very active plant bug about one-fifth of an inch in length. Early food punctures may cause deformed fruit.

The adults winter over among weeds and rubbish about the orchard, and breed principally on the weeds and under-growth. Occasionally they deposit their long white eggs in the fruit.

The nymphs or young are wingless, attaining their wings at about one month of age.

Remedies.—This is a very difficult insect to control, owing to its wide range of food-plants, and the fact that much of the injury is done by the winged adults which are very shy and active. Numbers 10 and 19 will be found to be of some value. Clean cultivation and the destruction of all hibernating places will also help much.

Scale Insects.—Some of the scale insects, especially the San Jose and Howard scales, will attack the fruit. The Howard scale is quite bad on plums in some sections, spotting the fruit and making it unsalable. (See under Apple and Pear.)

FOLIAGE

Green Peach Aphis.—A pale green or greenish yellow louse that hatches from the over-winter eggs early in the spring. It attacks the blossoms and small fruits, causing many to drop, and later attacks the leaves which curl and turn yellow. About mid-summer this louse

leaves the peach and goes to a large variety of other plants. It returns to the peach in the fall to deposit the over-winter eggs upon the twigs. This louse also infests the plum.

Remedies.—Spray after the eggs hatch and before the lice get into the opening buds with Black Leaf 40 (19), 1 part to 800 parts water; kerosene emulsion, 5 to 8 percent kerosene; or miscible oils. If the lice appear later, treat as in case of the green apple aphid.

Black Peach Aphid.—This louse, which is amber to black in color, attacks the peach only. It attacks the roots as well as parts above ground. It is on the twigs and foliage only until about mid-summer, but remains on the roots all the year.

Remedies.—For those above ground, treat the same as for green aphid on apple. For the root form, use the same treatment recommended for the root form of the woolly apple aphid.

This has not been a serious pest in Colorado, only an occasional tree having been found infested.

Green Plum and Prune Aphid.—This is commonly known as the hop plant louse, the hop being the summer food-plant. It migrates to the plum and prune in the fall to deposit the over-winter eggs. Winged lice return to the hop early in the summer.

Remedies.—The same as given for the green peach aphid.

Cherry and Pear Slug.—This is a dark-colored, slimy larva much resembling a small snail. The body is large in front and tapers behind. It feeds upon the upper surface of the leaves, often leaving only a skeleton to wither and die. The adult is a small, glossy black four-winged fly about one-fifth of an inch in length. This fly deposits her eggs in the tissue of the leaves just under the epidermis by means of a saw-like ovipositor, whence the common name of "saw-flies." There are two broods each year. This is a common pest on the cherry, pear, plum, quince and crabs. See Fig. 9.

Remedies.—White hellebore (7) 1 ounce to 3 gallons of water. arsenate of lead (4), Black Leaf 40, 1 part to 800 or 1,000 parts of water; freshly slaked lime (27), or wood ashes (26) dusted upon the slimy larvae will kill many. A strong stream of water will wash them from the leaves.

Fruit-Tree Leaf Roller.—This insect attacks the plum, prune and cherry quite severely, and the peach to some extent. (See under Apple).

Brown Mite and Red Spider.—These are often quite bad on peaches and plums. For description and treatment, see under Apple and Pear.

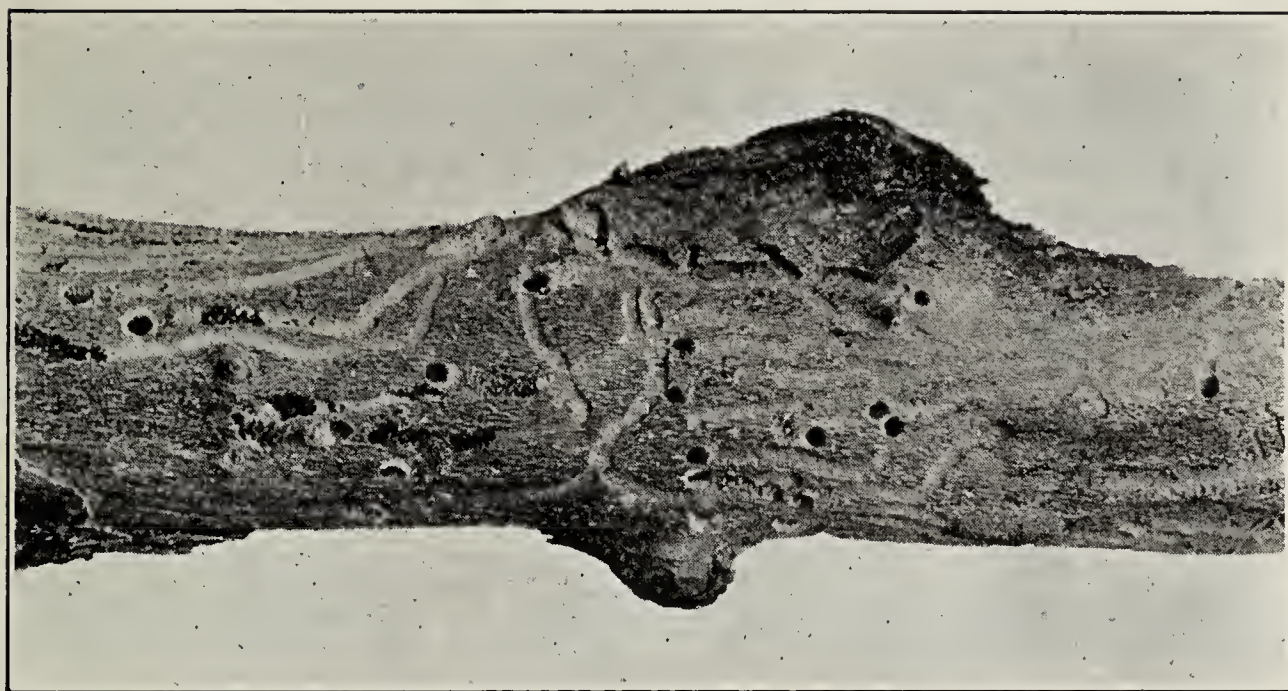


Fig. 18.—Small apricot limb with bark removed to show the galleries made by the larvae and adults, and holes made by the adults of the shot-hole borer or fruit-tree bark-beetle. Enlarged twice. After O. E. Essig, "Injurious and Beneficial Insects of California." Calif. State Com. of Hort.

BARK AND WOOD

Shot-Hole Borer.—Quite often cherry, plum, prune, peach and sometimes pear and apple trees are found that have numerous small holes in the bark. These will be about the size of a hole made by a small shot or the size of a pin head. These holes are made by the shot-hole borer as the adult beetles leave the trees. If the bark is cut away, numerous channels running between the bark and sap wood will be found. These are made by the grubs of the small brown beetles. See Figs. 18 and 19.



Fig. 19.—Adult of the Shot-hole Borer or Fruit-tree Bark-beetle. Enlarged five times. After O. E. Essig, "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.

This borer very seldom attacks healthy, vigorous trees. It seeks those that have been weakened by disease or injury.

Remedies.—Keep trees in a healthy, vigorous condition. Destroy all infested trees by burning. Whitewash (15) will help to prevent sunscald and will, to some extent, keep beetles from laying eggs on the trees.

Scale Insects.—See under Apple and Pear.

Peach-tree Borer.—A yellowish-white borer about one to one and one-quarter inches in length when full grown. It bores beneath the

bark of the lower trunk, crown and larger roots, often killing small trees by girdling them and damaging larger trees so much they are of very little value. The adult is one of the clear winged moths, and may be mistaken for a wasp. Besides the peach, this borer infests plum, prune, cherry and apricot. See Fig. 20.

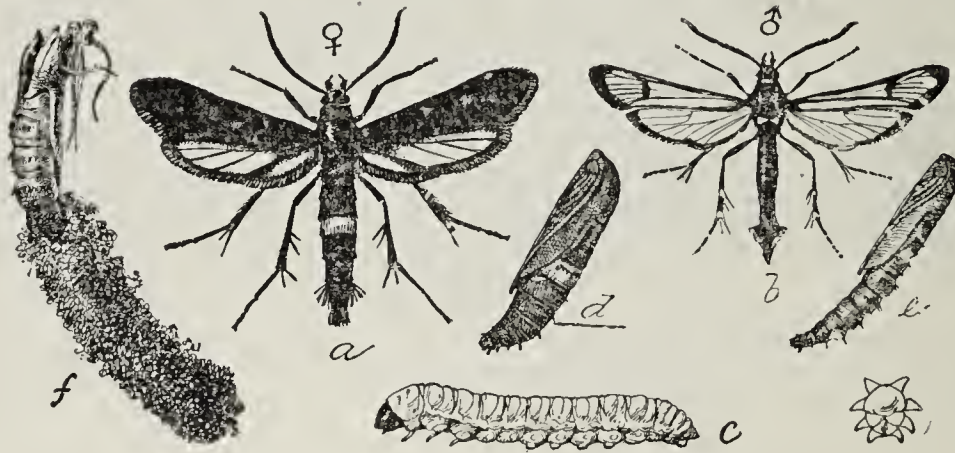


Fig. 20.—Peach-tree Borer: a, adult female; b, adult male; c, full-grown larva; d, female pupa; e, male pupa; f, pupa skin and cocoon. All about natural size. (Marlatt, Circular 17, Second Series, U. S. Dept. of Agriculture, Division of Entomology.)

Remedies.—Carefully inspect the trees every fall and spring and remove all borers with a knife. It may be necessary to remove some soil from about the crown to find all borers. Their presence is usually indicated by a gummy exudation upon the bark. A shield of paper about the trunk from June 1 to August 1, the egg-laying period, will aid in keeping the adults from laying eggs upon the bark. Asphaltum painted upon the trunks has been used for this purpose, in California with some success. See Fig. 21.

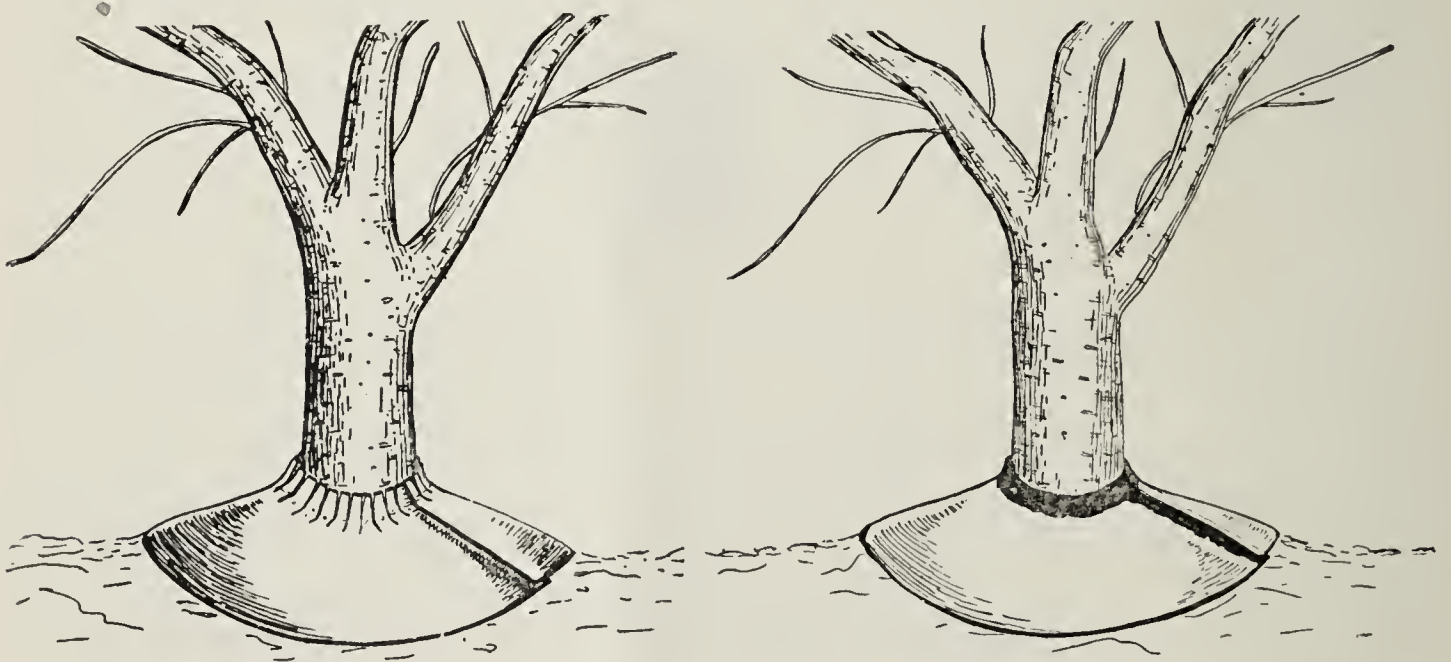


Fig. 21.—Showing a type of tree protector that gives results in controlling the peach-tree borer. No. 1 shows the protector in place but not sealed to the tree. The adult lays her eggs on the trunk of the tree, the small newly hatched borers are unable to penetrate the dry tough bark of the tree trunk, so endeavor to crawl to the soil where the bark is moist and tender. The cone-shaped protector prevents them from reaching the base of the tree, and they soon perish. The protector must be closely sealed to the tree and all seams closed. (Loaned by the Scott Tree Protector Co., Baltimore, Md.)

CURRANT AND GOOSEBERRY

FRUIT

Fruit Worm.—This is a flesh-colored worm about two-thirds of an inch in length when fully grown. It attacks both the gooseberry and currant in some parts of Colorado, and may destroy a considerable portion of the crop by eating large holes into the berries. It may enter a berry and eat out the interior and go on to another. Clusters of fruit and leaves are often loosely webbed together. The adult insect is a gray moth with rather long, narrow wings. See Fig. 22.

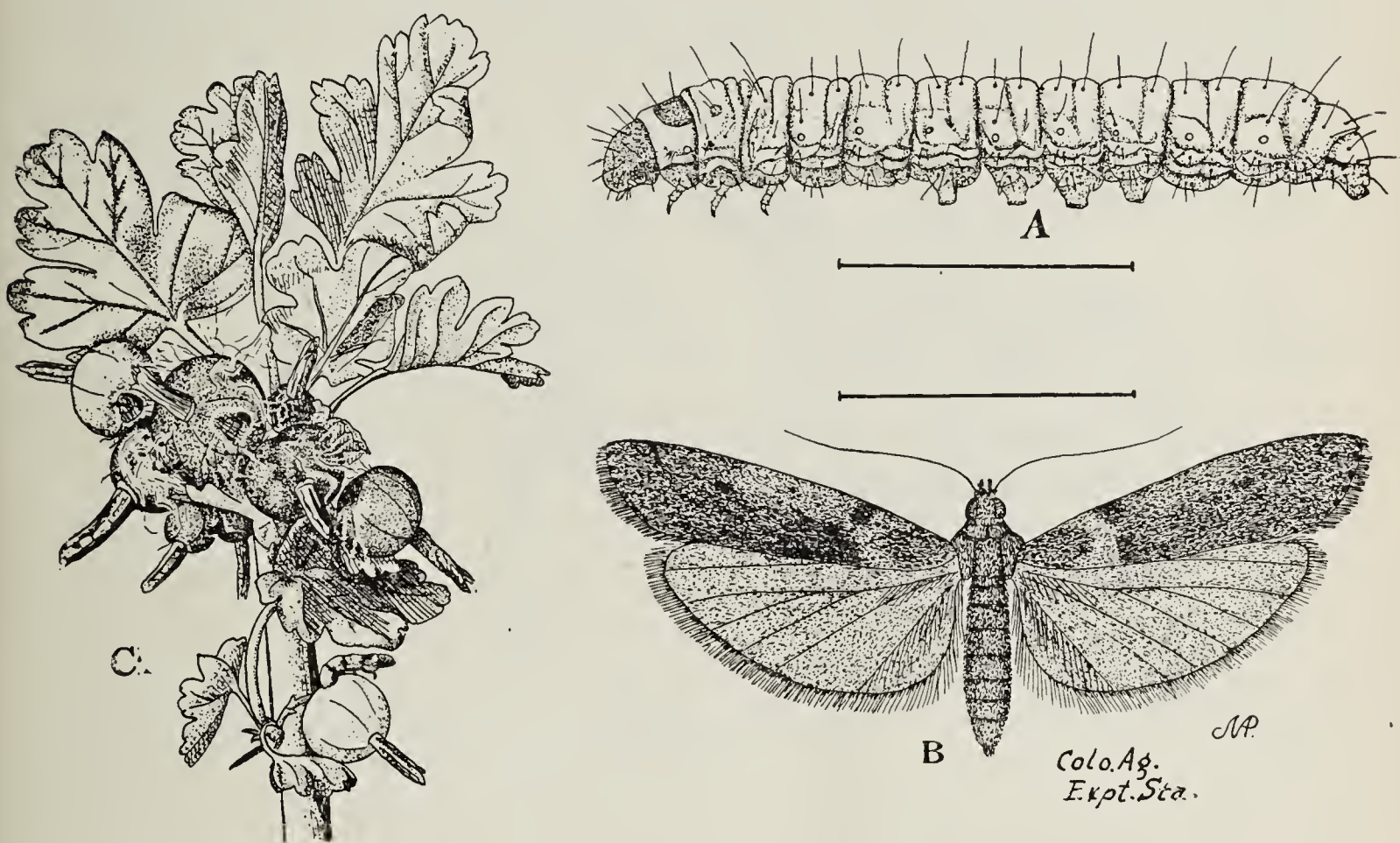


Fig. 22.—Currant and Gooseberry Fruit-worm; A, worm; B, moth; C, gooseberries webbed together. Original in Bull. 114, Colo. Agr. Col.

Remedies.—Hand picking is probably the best remedy. Destroy all web clusters. This is practical only on a small scale. Poison sprays would kill many, but would make fruit unsafe for food. Thorough cultivation will destroy many of the over-wintering chrysalids.

Fruit Maggot.—This is one of the most serious pests of the gooseberry and currant in Colorado. It is a small, white maggot which feeds within the fruit, causing it to turn red and drop. The adult is a two-winged fly about the size of an ordinary house fly, but yellowish-brown in color, with dusky bands across the wings. It comes out in the spring when the berries are about half grown and stings the fruit with its sharp ovipositor and deposits its eggs beneath the skin. In about three weeks the full grown maggot leaves the fruit and enters

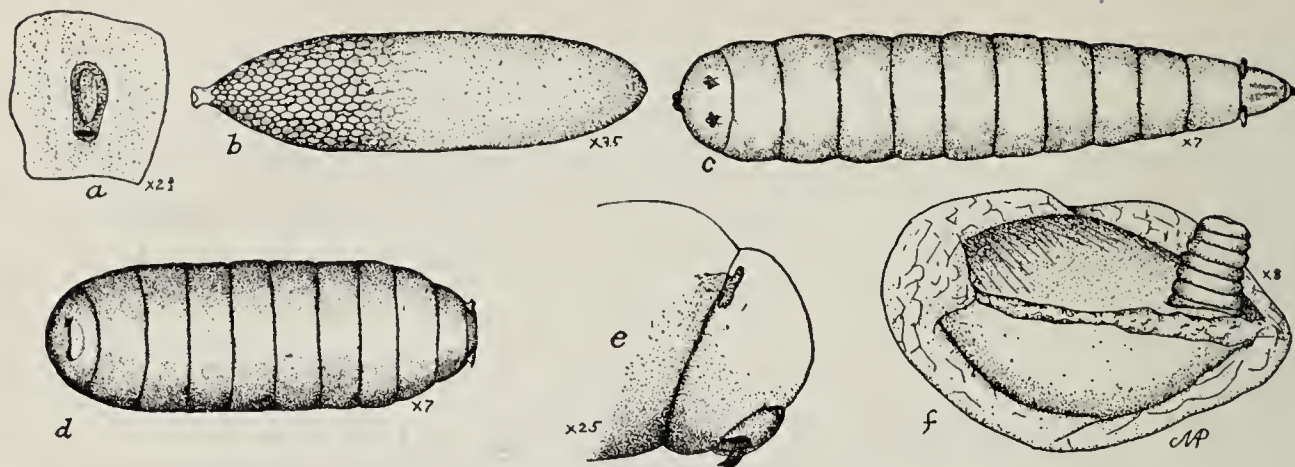


Fig. 23.—Curraan and Gooseberry Fruit Maggot; a, egg puncture made in the berries by the adult flies; b, egg; c, larvae; d, pupa; e, head end of larva showing sharp jaws beneath; f, larva entering a seed; a, enlarged $2\frac{1}{2}$ times; b, 35 times; c, d, 7 times; e, 25 times; f, 8 times. Original, Miriam A. Palmer, Delineator.

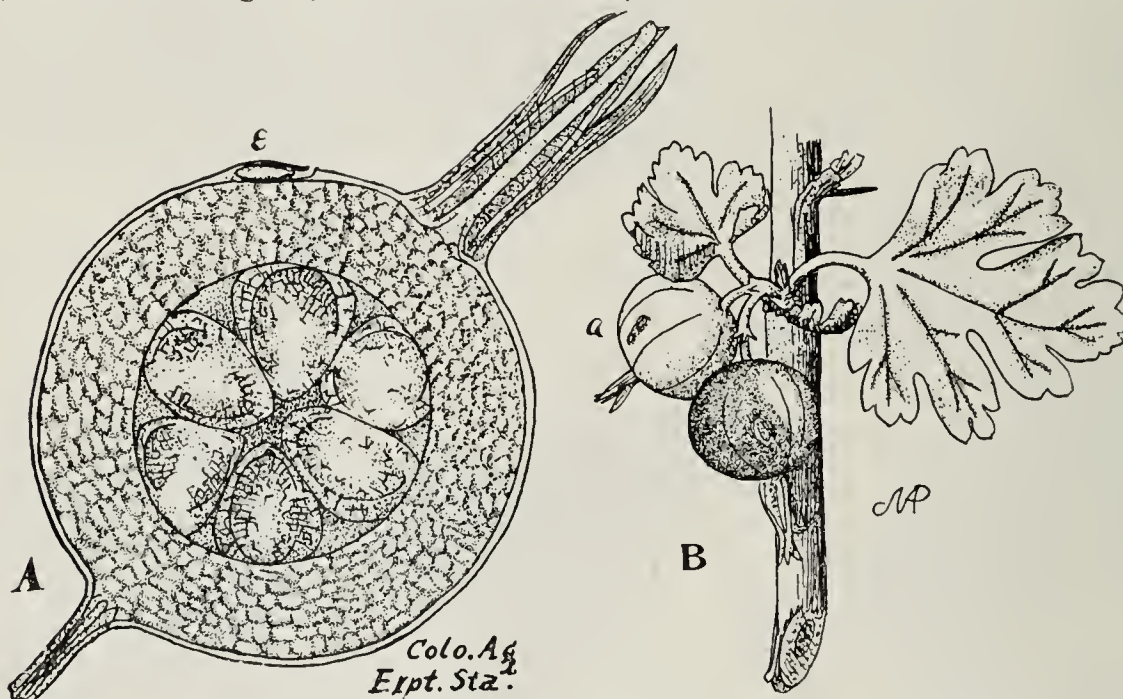


Fig 24.—Curraan and Gooseberry Fruit-maggot: A, section through a gooseberry showing egg and puncture at e; B, two gooseberries on a stem showing egg puncture, or sting, at a. Original in Bull. 114, Colo. Exp. Sta.

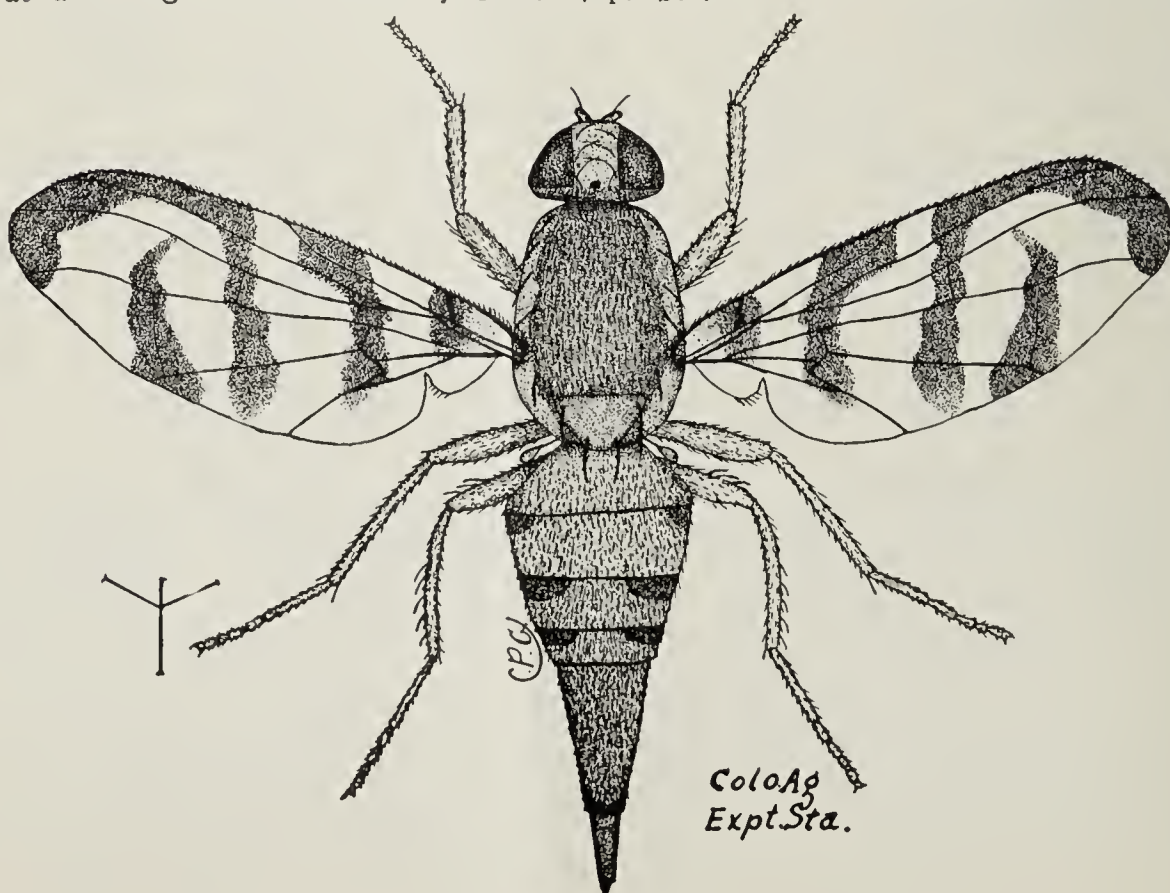


Fig. 25.—Adult of Curraan and Gooseberry Fruit-maggot.

the ground where it hibernates. There is only one generation a year. See Figs. 23, 24 and 25.

Remedies.—No practical method of control has been found. Collecting and destroying the infested berries will help, but is impractical, except on a small scale. Thorough cultivation to destroy the hibernating form will help. Chickens running among the bushes will destroy many.

FOLIAGE

Native Saw Fly.—A light green worm with a blackish head that feeds upon the leaves of currant and gooseberry bushes. The first brood appears in June and the second in August. The adult insect is a black four-winged fly about the size of the house fly that appears in the spring while the leaves are small, and inserts the whitish eggs in the edge of the leaf between the two outer layers. The eggs form a blister-like elevation on the leaf.

Remedies.—Four pounds arsenate of lead (4) or 1 pound Paris green (2) in 100 gallons of water will be found effective. These should not be used before the fruit is picked. The following may be safely used on the fruit, and are quite effective: White hellebore, 1 ounce to 3 gallons of water, or in the evening, thoroughly dust the leaves with the hellebore, or with pyrethrum.

Imported or European Saw Fly.—This pest has only recently been reported in Colorado. It is very similar to the preceding species, but is much more destructive. The larva can be distinguished from the native species by its dark head and numerous black specks on the body. The adult is somewhat larger than our native species. The small white eggs are placed in rows along the veins on the under side of the leaves.

Remedies.—Same as for the preceding species.

Currant Plant Louse.—The eggs are small shining black objects, and rather long in shape. They hatch, about as the buds begin to open, into a yellowish-green louse that feeds upon the opening buds and later upon the under side of the leaves. The numerous food punctures cause the leaves to curl and turn red and yellow in color. The lice remain on the currants all the season. Their favorite plant is the red currant, but they also attack the black currant and gooseberry.

Remedies.—Same as recommended for green apple aphid. The leaves curl so tightly, spraying must be done before they begin to curl, for best results.

Brown Mite and Red Spider.—These mites are often very abundant on currant and gooseberry. It is not uncommon to see bushes largely defoliated by them as early as July. See under Peach Foliage.

BARK AND WOOD

Currant Borer.—A yellowish white larva, about one-half inch in length when mature, that tunnels into the canes, often killing them. It hibernates within the canes and comes out as a wasp-like moth in June. The moth very much resembles that of the peach borer, but is smaller. Infested canes can often be detected by the withered yellowish appearance of the foliage or the small burrow made to the surface.

Remedies.—Cut out and burn all infested canes as soon as detected. Keep the old wood well trimmed out.

Scale Insects.—The San Jose. Putnam, Oyster-shell, and several other species of scale insects may attack the currant and gooseberry.

STRAWBERRIES

Leaf Roller.—Small greenish-brown caterpillar that webs the two halves of the leaves together and feeds within the roll causing the leaves to wither and die. So much of the foliage may be destroyed that the fruit will not mature properly. See Figs. 26 and 27.

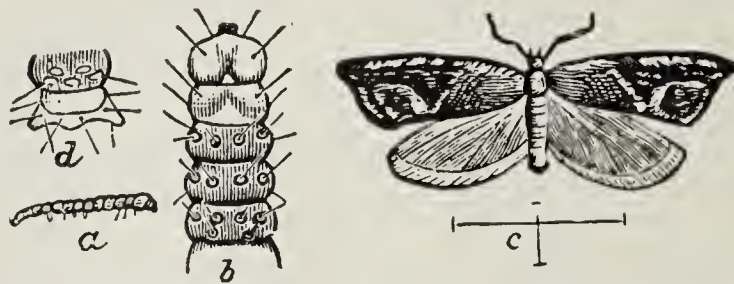


Fig. 26.—Strawberry Leaf-roller; a, larva, natural size; b, head end of larva enlarged; c, moth about twice natural size; d, tail end of larva enlarged. (After Saunders.)

The adult insect is a small dark brown or rust-colored moth with white markings on the wings; about one-half inch across expanded wings. It also attacks the raspberry and blackberry.

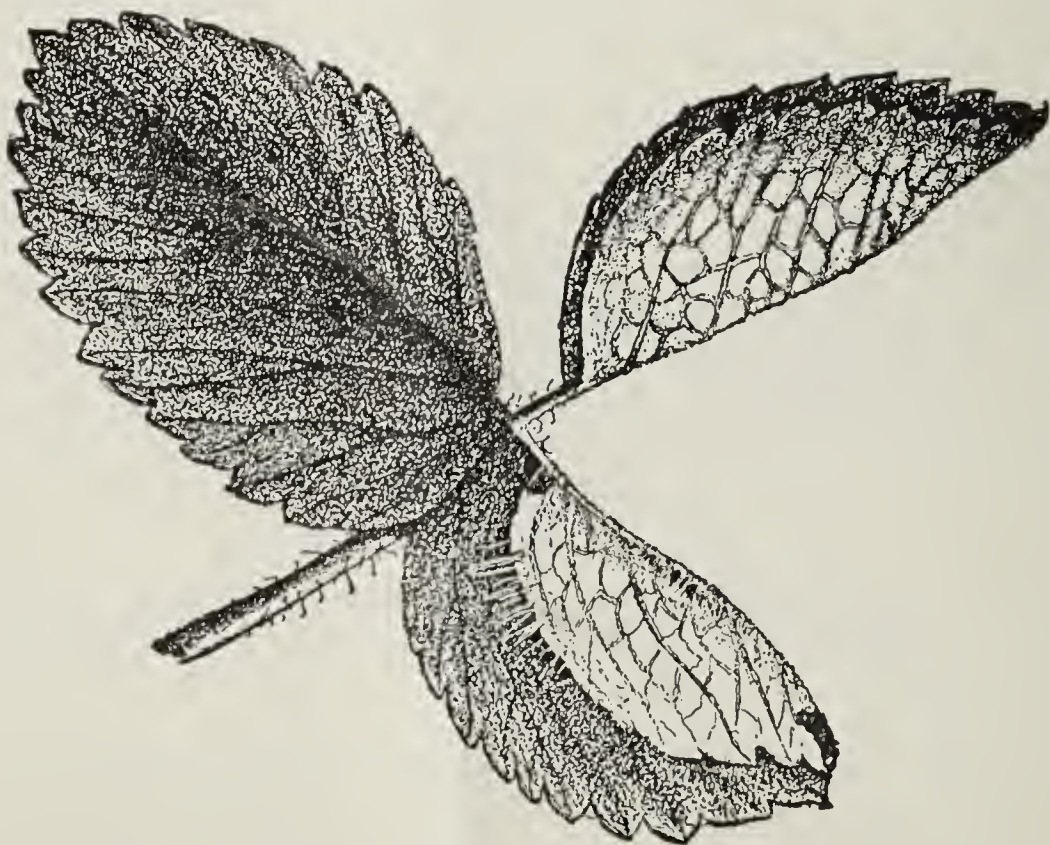


Fig. 27.—Strawberry leaves showing their appearance after being folded. (After Weed.)

Remedies.—New Jersey Experiment Station, Bulletin 225, reports success with arsenate of lead (4), 5 pounds to 100 gallons of water, applied before the leaves are rolled, or about one week after the moths appear in the spring. After the fruit is gathered, scatter straw over the plants and burn.

Strawberry Crown Borer.—This is a yellowish-white grub that eats into the crowns of the plants. It is the larva of one of the snout beetles.

Remedies.—Do not allow beds to get too old. If badly infested, gather only one crop before renewing. Place the new beds some distance from old ones. Burning over as recommended for preceding species is of some value.

Red Spider.—Often attacks strawberries. For remedies see under Apple, Peach and Pear.

RASPBERRY AND DEWBERRY

Raspberry Saw Fly.—A light green larva about three-fourths of an inch long when fully developed, that eats irregular holes in the leaves. The small white eggs are deposited within the tissue of the leaves by a fly resembling the cherry saw fly.

Remedies.—Same as for Saw Flies on currants and gooseberries.

Cane Borer.—Small cylindrical borer that eats into the new shoots during early summer, causing them to wither. It remains in the canes during second season eating downward through the pith, often killing the cane before the fruit matures.

Remedies.—Cut off all affected canes and burn while the borers are still in them.

Red Spider and Brown Mite.—Often attack the raspberries and dewberries. For remedies see under Apple, Pear and Peach.

GRAPE

Leaf-Hopper.—Closely related and very similar to the leaf-hopper of the apple and pear. For description and remedies see under Apple and Pear Foliage. See Fig. 28.

Eight-Spotted Forester.—A caterpillar about one and one-half inches long when mature, dark colored with numerous small black and white cross lines on each body segment. The adult is a dark colored moth with eight light spots on the wings. See Fig. 29.

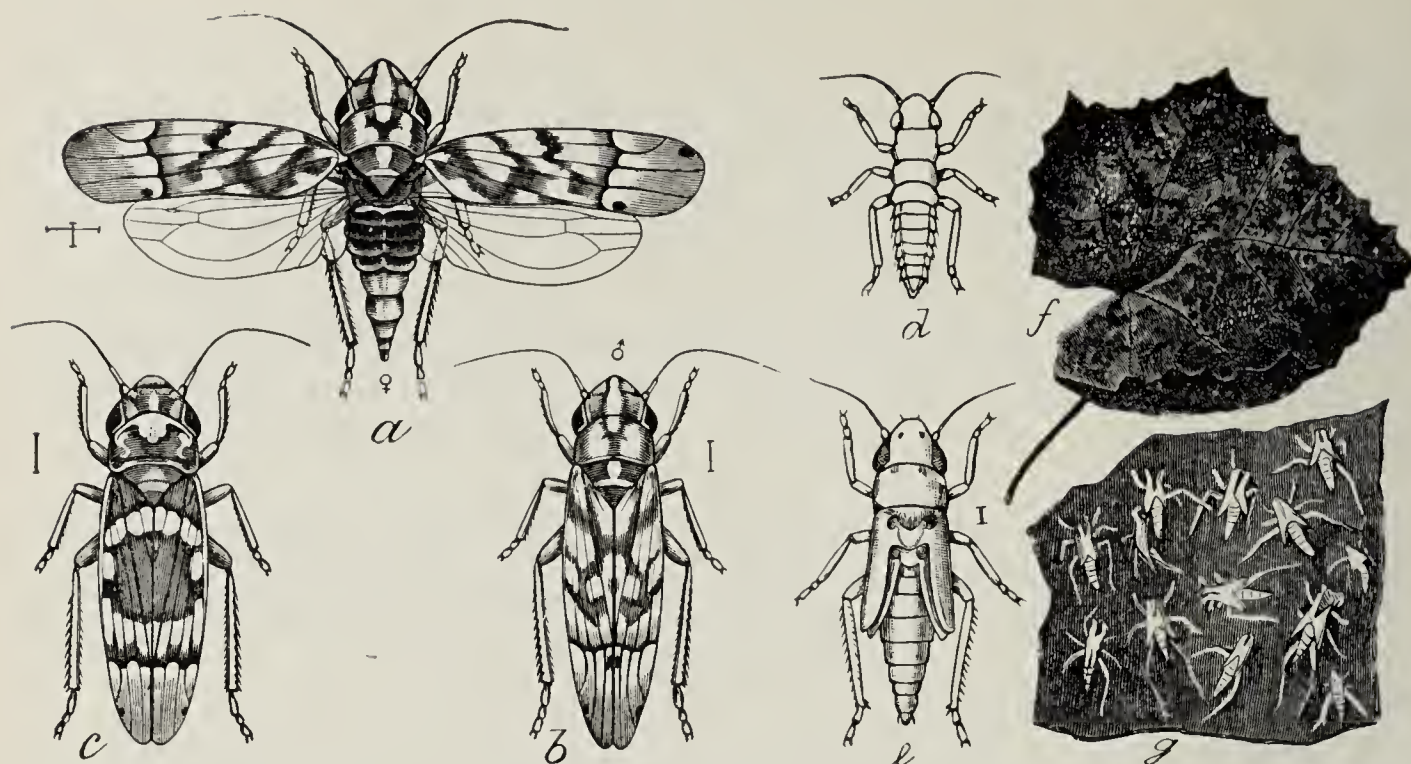


Fig. 28.—Grape Leaf-hopper; a, adult female; b, adult male; c, another form of the species, showing variation in markings; d, newly-hatched nymph; e, last stage nymph; f, appearance of injured leaf; g, cast pupa skins. a-e, much enlarged; g, less enlarged; f, reduced. (After Marlatt, U. S. Dep't. of Agr. Div. of Entomology.)

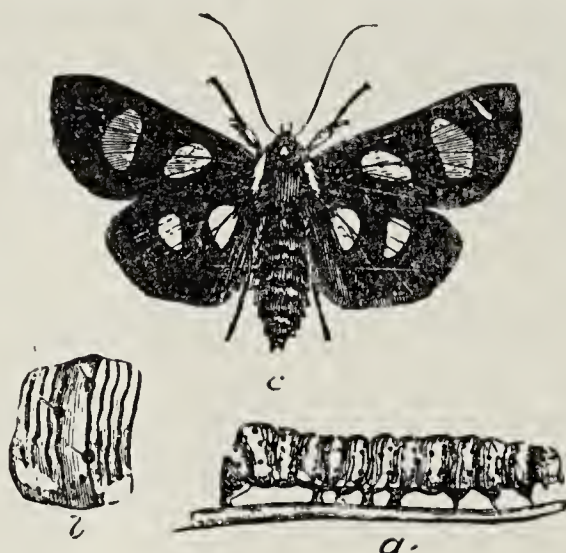


Fig. 29.—Eight-spotted Forester; a, larvae; b, one segment of body of larva enlarged; c, moth. Natural size, except b.

Remedies.—The arsenicals (2-4-5) will be found effective. In small vineyards hand picking might be found practical.

This insect also attacks the Virginia Creeper.

Cottony Scale.—See under Maple.

SHADE TREE PESTS

Cottony Maple Scale.—This insect winters over as partly grown brown scales on the smaller limbs and twigs. With the coming of spring the insect grows and throws out a white cottony secretion from the posterior end of the scale. During June, a mass of small creamy-white eggs are deposited in the cotton under the old scale. At this time the scales are very conspicuous. The eggs hatch during the last of June and early July and the young lice locate on the under side of the leaves. This is a common pest of the maple, and also infests black locust, elm, and many other trees and shrubs. See Fig. 30.

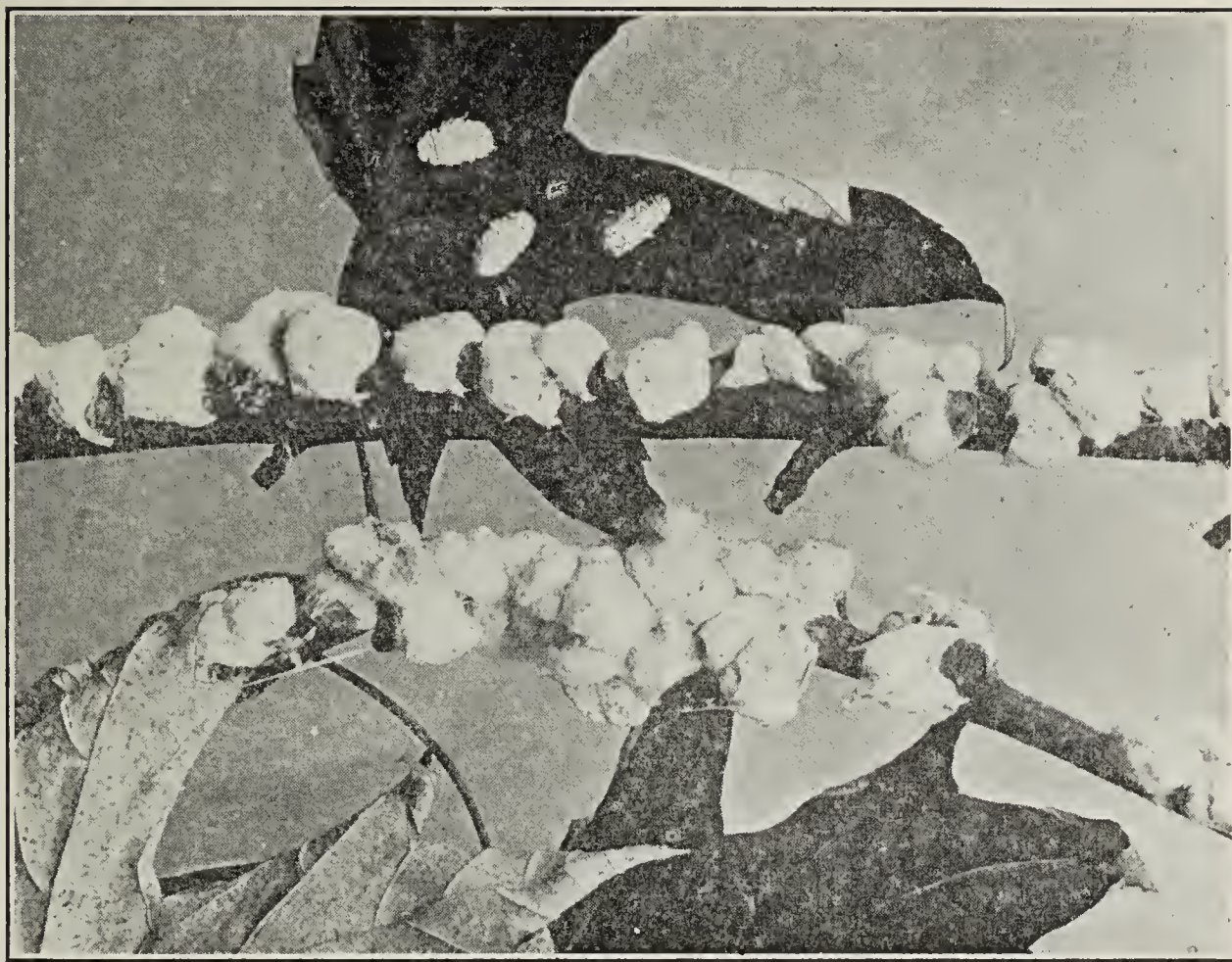


Fig. 30.—The Cottony Maple Scale. Mature females on maple twigs. Larvae of one of the lady-bird beetles, *Hyperaspis signata* Oliv. on leaf at the left. These lady-bird beetles feed on scale insects. Natural size. (After O. E. Essig, "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.)

Remedies.—Kerosene emulsion (10), 15% kerosene, used during the dormant season, will be found fairly effective.

Tobacco extract (19) or kerosene emulsion (10), that is 7% kerosene, will destroy the young insects, but it is difficult to strike all of them on the under side of the leaves. If a strong current of water can be used, many of the young insects can be washed to the ground where they will perish.

Elm Scale.—The young lice hatch in June or early July and feed upon the leaves until fall, when they return to the bark, insert their beaks and hibernate during winter. In the spring the eggs are deposited under the body and a partial scale formed over the females. The presence of the insects is best indicated by the partial scale which consists of a white, waxy ring secreted about the insect. Infests elms only. See Fig. 31.

Remedies.—In Nevada where this has been quite a serious pest, best results have been obtained by using soluble oils (12), 1 part to 15 parts water, during the dormant season. For summer treatment use kerosene emulsion (10) or tobacco (19), as recommended for the maple scale.

Oyster-Shell Scale.—In some sections of the State this scale is quite bad on the ash and lilac. For description and remedies, see under Apple and Pear, Bark and Wood.



Fig. 31.—The European elm scale on the American elm. Adult females as they appear in June. Natural size. (After O. E. Essig, "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.)

Locust Borer.—A white grub about three-fourths of an inch in length when fully grown, that feeds within the trunk and limbs of the black locust, destroying many trees. Small white eggs are deposited in crevices of the bark during the early fall by the adult insect which is a wasp-like beetle about three-fourths of an inch in length. These hatch the same fall and the little borers eat into the bark where they live over winter. They mature the following July and the beetles come out during late summer and early fall. The presence of the borers can be detected by the borings that are forced out of the burrows.

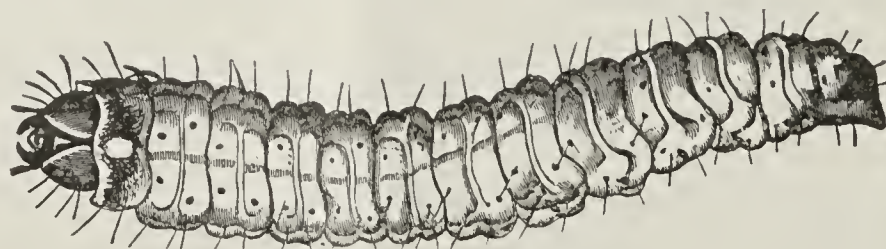


Fig. 32.—Larva of Cottonwood Borer.

Remedies.—Spraying is ineffective. Destroy all badly infested trees by burning. Many of the grubs can be killed and the life of valuable shade trees prolonged by squirting a small amount of carbon bisulphide into the burrows and plugging them with mud. This will necessitate going over the trees several times during early summer.



Fig. 33.—Cottonwood Borer, showing male and female moths. The female is larger.

Cottonwood Borer.—A large reddish caterpillar, head shining black, body somewhat flattened, and when mature about three inches long, bores large holes or galleries in the trunks of the cottonwoods and poplars. It transforms to a large thick-bodied moth in June and July. See Figs. 32 and 33.

Remedies.—This borer does not bring its borings out to the surface, so it can be detected only by the discoloration of the bark, due to sap leakage. The borers sometimes can be dug out with a stiff wire, or the channels opened and carbon bisulphide injected. (See under Locust Borer.)

Boxelder Leaf-Roller.—This is very similar in appearance and habits to the Fruit Tree Leaf-Roller. It seems to attack boxelder exclusively in Colorado.

Remedies.—See under Fruit Tree Leaf-Roller.

Plant Lice on Ash, Elm, Willow, Boxelder, Locust, etc.—Most all of our shade trees and shrubs are subject to the attacks of one or more

species of plant lice. These vary somewhat in appearance and habits, but are all subject to the same treatment. Use contact sprays, as kerosene emulsion (10), tobacco (19), or soap (8).

ORNAMENTAL PLANTS

ROSE

Plant Lice.—The rose is subject to the attacks of several species of plant lice.

Remedies.—Use contact sprays (10), (19), (8), being careful to spray the under side of the leaves where most of the lice will be found.

Saw Fly.—This is a greenish-yellow larva about one-half inch in length when fully grown, that eats the upper surface of the leaves leaving only the veins and lower epidermis. The adult is one of the saw flies very similar to the adult of the pear and cherry slug.

Remedies.—See under Pear and Cherry Slug. A strong stream of water will wash many of the larvæ from the leaves.

Leaf-Hopper.—The rose is quite commonly attacked by leaf-hoppers, closely related and very similar to the species attacking the apple and pear. For description and remedies, see under Apple and Pear Foliage.

The young wingless hoppers can be washed off the foliage with a strong stream of water and many of them killed.

Rose Scale.—This is a snow-white, nearly circular scale about one-tenth of an inch in diameter. It often infests blackberries, raspberries, and dewberries, as well as roses. See Fig. 34.



Fig 34.—The Rose Scale on wild blackberry. Only slightly enlarged. After O. E. Essig. "Injurious and Beneficial Insects of California." Calif. State Com. of Hort.

Remedies.—Spray during dormant season with No. 8, 16 or 17. The soap should be used one pound to one gallon of water.

VIRGINIA CREEPER

Eight-Spotted Forester.—See under Grape.

The Achemon Sphinx.—A hairless caterpillar that feeds upon the foliage. It resembles the large tomato "worm." When small it has a long spine on the last body segment. When nearly full grown the

spine is represented by a shining black spot.

Remedies.—Hand picking will usually keep the insect in control. The arsenicals, 2, 4 and 5, are quite effective.

SWEET PEAS

Red Spider.—Many growers of this common flower find the lower leaves turning yellow and falling, and the vines stopping growth. This is usually due to the work of the Red Spider.

For description and remedies, see under Peach Foliage. Frequent drenching with the garden hose will do much to keep the spider in check and prevent its injuries.



Spraying from a home-made tower.

PART II.

INSECTICIDES

THEIR PREPARATION AND USE

There are two general classes of insecticides, those used against insects which have jaws and bite off and eat parts of the leaves, fruit or whatever they feed upon, and those used against sucking insects that have mouth parts in the form of a beak or slender tube through which they draw the juices of plants or the blood of animals.

For biting insects, some form of an arsenical compound, such as Paris green or arsenate of lead is commonly used and the insects are killed by eating the poison. For the sucking insects, which take their food from inside the plants, some of the contact insecticides such as kerosene emulsion, lime and sulphur or tobacco, must be used.

Contact sprays are often very effective in destroying the eggs of insects, especially those that winter over in the egg stage, as this will permit of spraying during the dormant season when a stronger solution can be used without injury to the plants.

Insecticides are generally used in one of three forms—liquid spray, powder, and fumes or vapor.

SUBSTANCES THAT KILL BY BEING EATEN

Arsenic in some of its compounds is the cheapest and most efficient poison used. As a very small amount of soluble arsenic is injurious to vegetation, only the insoluble compounds can be used.

I. WHITE ARSENIC

Pure white arsenic, arsenic trioxid (As_2O_3), which comes in the form of a white powder, is the cheapest form in which arsenic can be obtained, but since in this form it is soluble in water, it cannot be used as an insecticide where it is applied directly to vegetation.

2. PARIS GREEN

This is an arsenite of copper. It contains about 58% of arsenic (As_2O_3). The National Insecticide Law requires that it contain a least 50% of arsenic trioxid.

For many years this was a standard arsenical insecticide for orchard use, but owing to the danger of injury to foliage, from some soluble arsenic present, it has been largely replaced by less soluble arsenical compounds.

Paris green is often used in the dry form for dusting on plants. In this case it is better to dilute with some other material, such as flour, slaked lime, or plaster.

A good proportion is:

Paris green	1 pound
Common flour, lime or plaster	25 pounds

The flour will prove better than the other materials, as it will not be distasteful to insects and will adhere better to foliage.

When the Paris green is applied in a watery spray, the most common strength is:

Paris Green	1 pound
Water	160 gallons
Lump lime	2 pounds

For stone fruits it is safer to use 200 gallons of water. Make the Paris green into a paste, then slake the lime in a small amount of water and add to the Paris green. Dilute until it can be strained into spray tank. Keep the liquid thoroughly stirred during application, as the Paris green settles out very quickly.

3. POISON BRAN MASH

The following poison bran mashes have been found quite effective in destroying grasshoppers in orchards and vineyards, and army worms and cutworms when abundant:

White arsenic or Paris green	1 pound
Bran	20 pounds
Syrup	2 quarts

This formula has been used for a number of years, but Professor George A. Dean of Kansas has developed the following formula that is highly recommended:

Paris green	3 pounds
Bran	50 pounds
Syrup (cheap)	4 quarts
Water	5 gallons
Lemons	40

Mix the Paris green and bran together while dry; dissolve the syrup in the water; squeeze the lemons into this and finely chop the peel and pulp and add them also; pour this mixture into the bran and Paris green, and stir so as to dampen the mash thoroughly. The lemons may be prepared by putting them through a meat grinder. Distribute the mixture broadcast in as fine particles as possible where the grasshoppers are most abundant. The application should be made towards evening or early (between 4 and 7 o'clock) in the morning. From 3 to 5 pounds of dry bran is usually sufficient for an acre of land. Never distribute in little piles. For army worms, distribute more freely just ahead of the line of march.

4. ARSENATE OF LEAD

Arsenate of lead (paste)	3 to 6 pounds
Water	100 gallons

It is better to purchase arsenate of lead than to attempt to make it. This is the standard spray for codling moth and other biting insects. It has replaced the other arsenicals in practically all cases.

This poison is so completely insoluble in water that it can be used in most any strength without injury to foliage or fruit. The fineness of the particles causes it to settle very slowly, and consequently it can be more evenly distributed than most arsenical compounds. In adhesiveness it is superior to other arsenicals, but has the fault of not killing as quickly as Paris green.

Arsenate of lead is sold in both the form of a paste and as a powder. Under the National Insecticide Law, the paste must not contain more than 50% water and must contain arsenic equivalent to 12½% arsenic trioxid (As_2O_3). The water soluble arsenic must not exceed the equivalent of three-fourths of one percent of arsenic.

The paste has been more generally used than the powder, but if the powder is fine enough to remain in suspension when mixed with water, the results will be as good. One pound of powdered arsenate of lead is equivalent to two pounds of the paste form.

In preparing both the paste and powder forms for the spray tank, mix them first into a very thin paste. Never throw them as a mass into the spray tank.

5. ZINC ARSENIC

This is an arsenical compound that is comparatively new as an insecticide. It is being quite extensively used on the Pacific coast as a substitute for arsenate of lead. This is a light fluffy powder containing arsenic equivalent to 40 percent arsenic trioxid. It goes into suspension in water very readily and remains in suspension better than arsenate of lead or Paris green. In 1912, severe burning resulted in many apple orchards on the Western Slope where it was being tried out by the growers. One pound is equivalent to three pounds of arsenate of lead.

6. BORDEAUX MIXTURE AND THE ARSENITES

Bordeaux mixture has been a standard fungicide for many years, and besides the fungicidal properties, it acts as a repellant to certain insects, especially the flea-beetles. It has also been demonstrated that it has the effect of lessening the burning effect of Paris green, arsenite of zinc and other arsenicals, without injuring their poisoning qualities. Such a mixture will destroy both insects and fungi at one application.

A standard formula for Bordeaux mixture is:

Bluestone (copper sulphate)	4 pounds
Lime (unslacked)	5 pounds
Water	5 gallons

Dissolve the blue stone by suspending it in a sack in water, then dilute to 25 gallons. Slack the lime into an even creamy paste and then pour it into the bluestone solution slowly and dilute to 50 gallons. Never add the concentrated lime solution to the bluestone solution until the latter has been diluted.

If poisons are to be used with the Bordeaux, use them according to the proportion given for the different poisons, considering the Bordeaux as water.

7. WHITE HELLEBORE

Hellebore is a yellowish white powder made from the roots of a plant (*Veratrum album*) belonging to the lily family. It, being a vegetable poison, is not injurious to foliage. It is very effective against certain insects, especially the slugs which are the larvae of saw flies.

When exposed to the air, hellebore loses its strength, so a fresh article should always be demanded. Due to this fact, it is considered safe to use it on ripening fruit. It is often used on the cherry to control the cherry slug up to picking time. It is applied both dry and in water. When applied dry, it may be used without dilution.

When applied in water use:

White hellebore	1 ounce
Water	3 gallons

SUBSTANCES THAT KILL BY EXTERNAL CONTACT

Contact insecticides are especially effective against soft bodied insects.

Contact sprays have been developed, primarily, to use against sucking insects, but many of the chewing insects may be destroyed by them. To get results, thoro spraying must be done, as only those insects that have the material thrown directly upon them will be killed.

8. SOAP

Soap solutions are often used as contact insecticides against plant lice. Quite often, if one has only a few small trees or bushes in the garden, they may be treated with a solution of ordinary laundry soap, one pound to six gallons of water.

The whale oil or fish oil soaps are more effective. Use one pound to six to ten gallons of water.

9. FISH OIL SOAP (HOME MADE)

Slingerland and Crosby in their "Manual of Fruit Insects" give the following formula for the preparation of fish oil soap:

Caustic Soda	6 pounds
Water	½ gallon
Fish oil	22 pounds

"Completely dissolve the caustic soda in the water, and then add the fish-oil very gradually under constant and vigorous stirring. The combination occurs readily at ordinary summer temperatures and boil-

ing is not necessary. Stir briskly for about twenty minutes after the last of the oil has been added."

Use:

Soap	1 pound
Water	6 to 10 gallons

10. KEROSENE EMULSION

Soap (whale-oil or common soap)	½ pound
Water	1 gallon
Kerosene	2 gallons

Dissolve the soap in the water by boiling. Remove from the fire, and while still hot mix with the kerosene. Agitate vigorously by driving it through a spray pump until the oil is well emulsified and a uniform cream-colored mixture is produced. Small amounts may be emulsified by stirring vigorously, or by using a rotary egg-beater.

Dilute this stock solution by using one part to 10 or 12 parts water for a summer spray. For use on dormant trees, use one gallon of the stock solution to 5 to 7 gallons of water.

The strength of an oil emulsion depends upon the percent of oil it carries. The strength of the emulsion to use is often indicated by this percentage.

To obtain the amount of dilution to secure a certain percent, divide the percent of kerosene in the stock solution by the percent desired in the diluted emulsion and the result will be the amount to which one gallon should be diluted. As one gallon of the stock solution made according to the above formula will carry sixty-six and two-thirds percent of kerosene, to obtain the amount to which it should be diluted to get a 12½ percent emulsion, divide 66 2-3 by 12½, which gives 5 1-3. One gallon diluted to make 5 1-3 gallons will give a 12½ percent emulsion.

Summer sprays should carry from 5 to 7 percent kerosene, and sprays for dormant trees from 10 to 15 percent.

11. KEROSENE AND CRUDE PETROLEUM

These oils are sometimes used pure as insecticides. Some years ago they were used quite extensively in parts of the East in special spraying machinery that diluted them with water as they were being applied to the trees. Other sprays equally effective and much safer to use on trees have taken their places. Many growers use them in painting or swabbing the clusters of woolly aphis that gather about wounds on apple trees.

12. SOLUBLE OR MISCIBLE OILS

There are several concentrated oil emulsions on the market known as soluble or miscible oils. These are used almost entirely as dormant

sprays against the scale insects and certain other insects that winter over in the egg stage on the trees. They are subject to the same criticism as all other oil sprays, that of being more or less injurious to trees under certain conditions. To lessen the danger of injury they should be applied only while the trees are dry and the temperature fairly high, at least several degrees above freezing. In their work in the Eastern states, they have found the danger of injury less if applied after the sap begins to flow, and just before the buds open.

Only "soft" water should be used in any of the oil sprays, as a very small amount of alkali will tend to break down the emulsion and give free oil.

13. GASOLINE

Gasoline is sometimes used as an insecticide. Its chief use is against bed-bugs. It is destructive to both the adults and eggs. It is applied pure by means of an oil can or hand atomizer. Keep all fire away until the building has been well aired.

14. TURPENTINE

Turpentine is used the same as gasoline, and the same precautions apply. It is more deadly to bed-bugs.

15. LIME

Lime, either wet or dry, is of very little value as an insecticide. It is sometimes used to dust trees that are infested with the cherry and pear slug, it causes the slugs to drop off and most of them perish. Any other fine dust will have the same effect.

Whitewash on trees destroys very few insects but often prevents sun scalding. A good wash for this purpose is made in the following proportions:

Lime (lump)	30 pounds
Tallow	4 pounds
Salt	5 pounds
Water to make it flow well.	

The Government recommends the following formula:

Lime (unslacked)	40 pounds
Salt	15 pounds
Rice flour	3 pounds
Spanish whiting	$\frac{1}{2}$ pound
Glue	1 pound
Water	5 gallons

Slack the lime and strain. Boil the rice and dissolve the salt and glue in warm water. Add the materials to the slaked lime in the following order stirring well all the time: salt, boiled rice, Spanish whiting, glue, and water. Let stand for a few days before using, then apply hot.

16. LIME-SULPHUR WASH

This is the safest and most effective spray that can be used against the San Jose and other kindred scale insects.

The old formula that is still quite generally used is:

Lump Lime	20 pounds
Sulphur	15 pounds
Water	50 gallons

The lime is slaked with hot water in the kettle or cooking vessel, the sulphur is then stirred in and about one-half of the water added, then cooked from 50 to 60 minutes, or until the liquid becomes of a dark red color, when it is ready to dilute to 50 gallons, and use. Best results are obtained when it is applied while hot.

17. HOME-MADE CONCENTRATED SULPHUR ..

Fruit growers who have considerable lime sulphur spraying to do can make their own concentrated solution. This can be made and stored in tight barrels for future use, and if properly made and diluted according to the amount of sulphur it carries, it is just as effective as the commercial preparations.

With the present prices of the commercial products the grower will find the home-made solution much cheaper, except for the original outlay for a cooking plant and storage barrels.

In making this mixture the same methods are used as given above for making the dilute solution, but the following formula is used:—

Lump lime (pure).....	40 pounds
Sulphur	80 pounds
Water	50 gallons

Use only the best grade of pure lump lime. In boiling, never allow the water to get below 50 gallons, as this amount is required to carry the sulphur in solution. A mark showing the 50 gallon line should be made on the kettle or on the stirring paddle. If the mixture is to be stored for future use, strain into an air tight container and keep where it will be above the freezing point.

Home-made concentrates are apt to vary more in strength or density than the commercial brands. For this reason, each cooking should be tested and diluted according to the amount of sulphur in solution. This test is made by the Baume hydrometer, an instrument made for testing the density of liquids.

The hydrometers are manufactured by the Bausch & Lomb Optical Company, Rochester, N. Y.

The following table taken from Bulletin 330, New York Agricultural Experiment Station will be found useful in making dilutions from the hydrometer readings.

Reading on Hydrometer, Degree Baume.	Specific gravity.	With each gallon of concentrate use for San Jose Scale:
35	1.3181	9 gallons water
34	1.3063	8½ gallons water
33	1.2946	8 gallons water
32	1.2831	7¾ gallons water
31	1.2719	7½ gallons water
30	1.2608	7 gallons water
29	1.2500	6¾ gallons water
28	1.2393	6½ gallons water
27	1.2288	6 gallons water
26	1.2184	5¾ gallons water
25	1.2083	5½ gallons water
24	1.1983	5¼ gallons water
23	1.1885	4¾ gallons water
22	1.1788	4½ gallons water
21	1.1693	4¼ gallons water
20	1.1600	4 gallons water
19	1.1507	3 2/3 gallons water
18	1.1417	3 1/3 gallons water
17	1.1328	3 gallons water
16	1.1240	2 4/5 gallons water
15	1.1153	2½ gallons water

18. TOBACCO

Tobacco in one form or another has come to be one of the most generally used and the most effective insecticides. In the shape of a fine powder it is sometimes used against flea-beetles; the dust made from the stems is one of the best remedies we have for woolly aphis on the roots of the apple trees.

19. TOBACCO EXTRACTS

There are several commercial tobacco preparations on the market. Those most generally used are “Black Leaf 40” and “Nicofume.” These both contain about 40 percent nicotine which is the poisonous principle in tobacco. This is one of the most deadly poisons known. It is soluble in water and entirely volatile when pure. In Black Leaf 40, the nicotine has been treated to form a sulphate which is non-volatile. Black Leaf 40 is used in strengths varying from 1 part to 800 parts of water to 1 part to 1200 parts. Three pounds of soap added to each 100 gallons will make it spread and stick better. When used against the woolly aphis, the soap will aid the mixture to penetrate the woolly covering of the lice.

Black Leaf 40 can be combined with arsenate of lead and lime-sulphur sprays, but should not be used with arsenite of zinc.

Nicofume is used almost entirely for green-house insects. The nicotine being volatile, it will not stay on the plants long.

Its principal use is to soak material from which a smudge is made. The nicotine is driven off and destroys the insects.

Tobacco decoction is sometimes made by steeping one pound of tobacco in 4 or 5 gallons of water. Do not boil, as this will volatilize the nicotine.

20. SULPHUR

Flowers of sulphur has been found to be very destructive to the mites and red spider. It can be dusted on the plants in the dry form or may be mixed with water, one pound to three gallons, and used as a spray. First stir the flowers of sulphur into a small quantity of soapy water and then dilute to the desired proportion.

The mixture must be stirred vigorously, as the sulphur settles very quickly.

21. HOT WATER

Hot water may be employed to kill insects and eggs upon dormant nursery stock. Temperatures from 135 to 145 degrees for 10 seconds are usually harmless to dormant plants, and will kill all aphids eggs.

In some tests made at the college, those trees submerged for 10 seconds in water of 145 degrees were slightly injured, but 5 seconds in this temperature killed plant lice eggs, and showed no injury to the stock. One hundred thirty degrees was not very effective on some eggs treated. Probably the safest and most effective temperature is 135 to 140 degrees, with 10 seconds submergence.

SUBSTANCES THAT KILL BY BEING INHALED

22. CARBON BISULPHIDE

This is a colorless liquid with a very disagreeable odor. It is very volatile and the fumes are poisonous to both plant and animal life. Its chief use as an insecticide is against household and granary pests, borers and under-ground insects. For household and granary pests, use one pint to each 1000 cubic feet of space or for each 100 bushels of grain. Place in shallow vessels so it will evaporate quickly. Keep building closed for 24 to 36 hours.

For borers, by means of an oil can, squirt a few drops of carbon bisulphide into openings made by the borer, then plug with mud. Ants can be destroyed by punching a hole or two in their nests and pouring in one or two ounces of the liquid, after which the hole should be closed, and a wet blanket thrown over the hill. It is sometimes used against the woolly aphids on apple roots by making several holes 6 to 12 inches deep and about a yard apart about the tree and pouring 1 or 2 ounces of the liquid into each hole. Close the holes immediately.

Caution: Keep all fire away while using this material, as the gas is very explosive when mixed with air.

23. HYDROCYANIC ACID GAS

This is the standard fumigant for most horticultural purposes, and is often used to destroy insects in dwellings and mills. Many states require all nursery stock sold within the state, to be fumigated with this gas.

The following formula has been adopted in most states as the standard for fumigating nursery stock:

Potassium cyanide (of 98 percent purity)	1 ounce
Commercial Sulfuric acid	2 ounces
Water	4 ounces

The above quantities are sufficient for 100 cubic feet of space. Submit the nursery stock to the fumigation for from 40 to 60 minutes. For fumigating dwellings, mills, clothing, and the like, it may be used even stronger, and should run several hours.

This gas is sometimes used in fumigating green houses, but as there is great danger of it injuring the tender plants, it should be used only by those of experience. For this purpose, the quantities given in the above formula are used to each 1000 cubic feet of space. Fumigate only at night, and while plants are dry, as sunlight and moisture make the gas more injurious to vegetation. Leave the house closed for 5 or 6 hours before airing, and air well before entering.

In mixing the materials, use only an earthen or wooden vessel, and add the materials in the following order:

First, put in the water, then add the acid slowly. Put the required amount of cyanide in a thin paper bag, and when all is ready, drop it into the liquid and leave the room as quickly as possible. The gas is very poisonous and almost odorless. One breath of it when strong may mean death. Never enter the fumigation room until it has been aired 30 minutes.

All buildings should be made as tight as possible before fumigation starts. Nursery stock may be fumigated in a tight box or a house prepared especially for this work. Such a house should be built with two thicknesses of matched boards, with building paper between. Ventilators should be provided and doors made tight-fitting.

Handle the potassium cyanide with great care remembering it is a deadly poison.

REPELLANTS

24. NAPHTHALENE FLAKES, GUM-CAMPHOR, AND MOTH BALLS

These are used as repellants against fleas, clothes moths, museum pests, chiggers, etc. Scatter the repellants about the infested materials. They are often used in insect boxes and packed in with furs, feathers, and woolen goods to keep out insects that feed upon these animal products. They are not used to kill insects.

25. COMMERCIAL REPELLANTS

There are several commercial repellants upon the market that are of some value in protecting stock from flies. These can be secured at most any drug store.

26. ASHES

Wood ashes dusted upon plants while they are moist, has the tendency to keep certain insects away, especially flea-beetles and cucumber beetles. It does not kill the insects, but makes their food distasteful.

27. LIME, PLASTER AND ROAD DUST

These are used like ashes as repellants against flea-beetles and cucumber beetles, but are of little or no use in destroying insects, except, possibly, the pear and cherry slugs.

INSECT TRAPS

28. LIGHTS

Many night flying insects are attracted by lights. The lights are placed over a vessel containing water with kerosene over the surface. The insects fly against the lights and fall into the kerosene and water. Many beneficial insects are also destroyed in this way, so it is doubtful if it is very practical except in rare cases. Not all night flying insects are attracted by lights. Such an insect is the codling moth. Some of those that can be caught in this way are the adults of the army-worm, cut-worms, corn, or boll-worms, and the beet web-worm.

29. BANDAGES

Burlap or other heavy cloth bands placed about the trunks of apple trees are very useful in capturing the larvae of the codling moth, as they leave the fruit and search protected places to spin their cocoons. If the loose bark is scraped from the trees, 50 to 60 percent of the larvae leaving the fruit can be caught. This is a very important help in cleaning up a badly infested orchard.

The bands should be of three thicknesses of cloth. Wrap the band loosely about the trunk, lap the ends, and fasten with a tack. They should be placed on the trees by the 15th of June. Remove them every ten days until the 20th of August, and kill all larvae, then remove when convenient after picking time.

30. HOPPER-DOZERS OR HOPPER-PANS

The hopper-dozers are useful in catching the jumping insects, especially grasshoppers. They consist of a large pan carrying water with kerosene on it, so arranged that it can be drawn across the field by a horse. The back of the pan should be extended until it is four feet high. The insects jump against this and fall into the water and oil.

31. STICKY MATERIAL

Bandages of sticky material are often placed around the trunks of trees to keep insects from climbing to the branches. The most

common of these is "Tree Tanglefoot." manufactured by O. & W. Thum Co., Grand Rapids, Michigan. Printers ink or any other sticky material may be used. Where any oily substance is used, it should be put on a heavy paper bandage so as not to come in contact with the bark of the trees.

THE APPLICATION OF INSECTICIDES

THE PUMPS

Much of ones success in controlling any of the insects will depend upon the efficiency of his spraying machinery. The spraying must be thoroly done, and at the right time to bring results. All pumps and supplies should be on hand and in good condition before it is time to start the work. The insects will not wait upon the tardy fruit grower.

Do not make the mistake of getting too small a pump. Small hand pumps have their place in spraying shrubbery and garden vegetables, but should not be purchased for orchard work. The larger hand pumps fitted to a barrel will do fairly good work in an orchard of medium to small trees, but in a commercial orchard the labor of pumping is too great, and is almost sure to result in a poor job being done. In such orchards, gasoline power outfits are most useful. They will carry a higher, more uniform pressure and do the work more cheaply. It is a matter of economy to use tanks that will hold 200 or 250 gallons.

All pumps should be fitted with brass valves, as the materials used will corrode valves made of other metals and harden and decompose leather valves. It is important to have the barrel or tank fitted with an agitator that will keep the liquid well stirred so the materials in suspension will not settle. The hose to which the nozzles are attached should be light as possible, yet strong enough to stand the high pressure.

APPLICATION OF DRY INSECTICIDES

There are various dust sprayers, both large and small, upon the markets. They are planned to distribute the dry insecticides upon the plants. The worst objection to these, especially the smaller ones, is that they do not feed regularly, hence do not give a uniform flow of powder.

Small trees and low plants can be treated by dusting the powder through a cheese cloth bag, but it will reach the upper surface of the leaves only. It is best to apply the dust early in the morning, or in the evening, when there is sufficient moisture to cause it to stick where it falls.

HOW TO SPRAY

Lack of thoroness in spraying causes more failures than any other one cause. If insects are to be killed by poisoning, it is important

to cover all their food with the poison; if they are to be killed with a contact spray, it must hit the insect. The first requisite is a man to hold the nozzle who knows what thoro spraying is and is not afraid to do it. The second is a pump that will give plenty of pressure, and the third is a nozzle that will break the liquid into fine particles. The liquid should be strained into the barrel or tank, so there will be no solid particles large enough to clog the nozzle.

With the poison insecticides, the best results follow when the leaf is covered most completely and uniformly with the spray mixture. This is best done by making a spray fine enough so that it will fall on the leaf in mist-like particles and dry there. The aim should be to cover every leaf in this way. In order to do this, it will be necessary to spray the tree from all sides and angles. Do not make the mistake of having the spray so fine it will not carry into the tree enough to reach the inner limbs.

In applying the contact insecticides, the spray should be coarse enough to wet the insects when it strikes them and to penetrate the woolly covering that some insects have.

In applying the first spray for the codling moth, when the object is to fill the calyx cups of the little apples with the liquid, the best results are obtained with a medium coarse spray that will thoroly wet all parts of the blossom end of the fruit. By this is not meant a spray made up of coarse drops, but one that is broken into fine particles, but still with body enough to carry 8 or 10 feet from the nozzle without going into a mist or fog.

It is important to have the nozzle on an 8 foot rod, at least, and at an angle of about 30 degrees. This will permit one to reach the higher parts of a tree and spray them from different angles. When spraying large trees, the work is greatly facilitated by having a tower arranged on the machine so that one man can spray from an elevated position. This is especially important in putting on the first codling moth spray. At this time a large percent of the little apples are directed upward and the spray can be thrown directly into the calyx cups.

NOZZLES TO USE

There are two types of nozzles that are used extensively, the Bordeaux type that throws a flat spray, the fineness and volume of the spray being regulated by the size of the stream that is thrown against a flat face of the nozzle; and the Vermorel or whirl-pool type that throws a cone shaped spray which may be graded from coarse to fine, depending upon the pressure and the size or the aperture in the plate. The latter have been greatly improved by giving

them a center drive that produces a solid cone of spray, instead of the hollow cone. With the solid cone there is less likelihood of missing parts of the plants, and the wind does not catch the spray as badly. Good work can be done with both types of nozzles.

STATION BULLETINS

All available bulletins will be sent free on request to residents of this State.

The following are bulletins that are available at the present time:

No.	Title
135.—	A Few Orchard Plant Lice.
150.—	Measurement and Division of Water.
157.—	Arsenical Poisoning of Fruit Trees.
168.—	Deterioration of Manures Under Semi-Arid Conditions.
169.—	Some Insect Mites Attacking the Peach in Colorado.
170.—	Thinning the Winesap.
172.—	Garden Notes.
173.—	Notes on a Dry Land Orchard.
174.—	Adobe as a Building Material for the Plains.
176.—	Productiveness and Degeneracy of the Irish Potato.
177.—	Hold-over Blight in Pears.
182.—	Colorado Climatology.
183.—	Deterioration in Quality of Sugar Beets.
186.—	Fixation of Nitrogen in Colorado Soils.
187.—	Feeding Experiment with Lambs.
188.—	Ration Experiments with Swine.
189.—	Cost of Beef Production on Enclosed Range.
190.—	Variation Studies in Brome Grass.
192.—	Home-made Cider Vinegar.
193.—	Nitrifying Efficiency in Colorado Soils.
194.—	Frictional Resistance in Artificial Waterways.
195.—	Small Fruits for Colorado.
196.—	Some Soil Changes Produced by Micro-organisms.
197.—	Hog Cholera and Necrotic Stomatitis.
198.—	Onion in Colorado.
199.—	Vegetable Growing in Colorado. Common Insects of the Garden.
200.—	Silos and Silage.
201.—	Mushrooms.
203.—	Farm Costs on the Colorado Agricultural College Farm.
204.—	Brisket Disease. High Altitude Disease of Cattle.
205.—	Yellow-berry in Wheat.
206.—	Spur Blight of the Red Raspberry.
207.—	Some Miners' Inch Measuring Devices.
208.—	A Study of Colorado Wheat.
209.—	Irrigated Agriculture in the San Luis Valley.
210.—	Insects and Insecticides.
211.—	Colorado Plants Injurious to Livestock.
212.—	Fungous Diseases of Colorado Crop Plants.
213.—	Poultry Raising in Colorado.
214.—	Forage Crops for Colorado Plains.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

COLORADO PLANTS INJURIOUS TO LIVESTOCK

—BY—

GEO. H. GLOVER and W. W. ROBBINS



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COLORADO PLANTS INJURIOUS TO LIVESTOCK

By GEO. H. GLOVER and W. W. ROBBINS

INTRODUCTION

Since Colorado is a mountainous state with a considerable area of the plains district "above water," it is reasonable to assume that grazing under open range conditions will always be an important factor in the livestock industry of the state. Poisonous plants have a special economic significance in the breeding and handling of livestock under these conditions. It is impossible to estimate with any considerable degree of accuracy the aggregate loss to the livestock industry from poisonous plants, but roughly estimating the known losses in certain counties, we may safely assume that it amounts to several millions of dollars annually.

The Experiment Station receives many letters of inquiry relative to plants that are suspected of being detrimental to livestock and many specimens are sent for identification. This bulletin is calculated to assist stockmen and farmers in the identification of poisonous plants, to offer a few suggestions relative to preventive and remedial measures and to site special conditions under which certain plants are known to poison animals. The authors have attempted, by illustration and description, to correct some popular errors in the identification of certain plants that in appearance have a striking resemblance, such as the death camas and wild onion. Again, space is given to consideration of several plants, like algae and corn smut, which are incorrectly thought to be poisonous.

CONDITIONS OF POISONING

It is important to know the conditions under which poisoning is most liable to occur. There can be no doubt that animals when left to themselves will by instinct exercise considerable judgment in the selection of their food. Experience has shown that more animals are poisoned when being crowded by the herdsman, and, in case of cattle, when they are handled at the time of "round-up." When being driven animals will grab at weeds that they would not otherwise touch.

When animals are very hungry they are not very particular in the selection of their food. Many disastrous cases of poisoning occur when cattle and sheep are taken directly from the yards to the ranges after a long shipment.

Larkspur, and probably some other plants, are known by experience to be far more poisonous when the foliage is wet from dew, rain or snow. When poisonous plants, like the death camas, start to grow in advance of the native grasses, they are eaten almost to the exclusion of everything else. An acrid, bitter or otherwise disagreeable taste does not always bar stock from eating the first green

food that appears in the spring time. Again in the late summer the native grasses often cure early from drought and injurious plants like loco and lupine remain green. It is obviously true that stock will eat most poisonous plants that are green in preference to grass that has dried up and this no doubt accounts for the loco habit being acquired more often in the late summer and fall.

The stage of growth has much to do in determining whether or not certain plants will be eaten at any particular season of the year. The larger species of larkspur and the water hemlock become coarse and objectionable after flowering and are seldom eaten. On the other hand some plants are relished throughout the period of their growth. The death camas is eaten with avidity just before the flowering stem is formed; equisetum is eaten more after being cured with the hay; and matured lupine with the seed pods appears to be relished by sheep. To analyze all of the conditions under which poisoning occurs seems to be a hopeless task. The subject is complex. In the realm of poisons we are still groping in the dark, and there are many mysterious cases of poisoning that are quite unaccountable.

The reputation of a plant as poisonous or non-poisonous may be affected by many circumstances. It is found to be true that certain parts of a plant may be poisonous while other parts are not, and that the quantity of poison in any particular part may vary widely under different soil and climatic conditions and at different periods of growth. It is necessary to know the entire history of a plant before declaring it poisonous or non-poisonous. For example, the poison in lupines is confined almost entirely to the seeds, and if cut before going to seed makes a fair quality of hay. In water hemlock the poison is found largely in the roots of the mature plant. In calabar bean the very poisonous alkaloid eserine is found in the cotyledons. In aconite seeds, the central part contains most of the aconite. Not only may the amount of poison in any particular part of a plant vary greatly at different stages of growth but it has been shown by Dr. J. P. Lodsby in Java that in case of cinchona the amount of alkaloid in the leaves varies greatly between night and day and that the alkaloid is formed in the leaves during the day and deposited in the branches or bark during the night. Because of the fact that the most active principle in most plants is not uniformly present in any particular part of the plant, there is, as might be expected, contradiction in rating plants as poisonous or non-poisonous. It is a matter of common observation that while a large number of animals in a herd may be poisoned, a few almost invariably escape, and all are seemingly under the same conditions. The number poisoned and the degree of poisoning depend upon three factors: The quality of poison, the quantity of poison, and the racial as well as individual susceptibility to the particular poison in question. There is the greatest diversity in animals as to susceptibility to poisons. In Prof. Rudolph Keber's text on Practical Toxicology is found the following information bearing on this subject: "The

smallest snail will withstand more strychnine than an adult man. Many of the strongest cardiac poisons have no action whatsoever upon insects. Great care is necessary in thus reasoning from even the effects noted in experiments with warm blooded animals approaching nearer to man. The rabbit can take more morphine than can a man of fifty times the animals weight. Doses of lead, nicotinic acid, etc., sufficient to fatally poison do not injure the goat. Amygdalin does not affect dogs, but it kills rabbits. The hedgehog takes, with apparent enjoyment, a dose of cantharides that would kill several persons under excruciating pain. The bite of the most venomous snake does not harm him; he can even accommodate no inconsiderable quantity of hydrocyanic acid. Whereas the frog is extraordinarily susceptible to the digitalis poisons they have no effect upon the toad."

Another factor that complicates the grazing of animals, on a range where there are poisonous plants, is the uncertainty of their feeding habits; this is especially true of sheep. It is not an uncommon experience to see sheep eating greedily of plants that they have not been seen to eat before and will not eat the day or week following. This seemingly unaccountable appetite may be manifested in eating either poisonous or forage plants and may be true of the entire band or a few individuals. When a few individuals have been poisoned, it is safer to conclude that they alone have been eating certain poisonous plants than it is to assume that they were the only ones that were susceptible. In most cases it will be found that a majority of the band will be eating largely of certain plants, and where the small species of larkspur and death camas are both growing they will eat largely of one or the other throughout the season. All things considered it is impossible to predict with any degree of certainty whether or not animals will eat of a particular poisonous plant if allowed to graze unmolested.

PREVENTIVE MEASURES

Much more can be accomplished in prevention of poisoning than in treatment of animals after they have been poisoned. This principle is generally recognized to be true in its application to all diseases, and is especially true in this instance, for the reason that under range conditions, horses and cattle, especially, are without an attendant and are often not seen for days or weeks at a time.

Stockmen are advised to become familiar with the most common poisonous plants, to know the season of the year or other conditions of poisoning, and to herd their animals away from dangerous areas. At the same time there is some danger in herding animals away from dangerous areas, as many stockmen will testify. Many stockmen who have practiced herding animals from the worst poison weed ranges, have still suffered heavy losses, and claim to have a smaller loss when the animals are allowed to roam at will and exercise their instinct unmolested in the selection of forage. It is true

that the driving of animals to places where there are but few poisonous plants is dangerous under conditions already mentioned, but nevertheless, much may be accomplished in preventing heavy losses by herding animals entirely away from poison weed areas.

Considering the immense area of grazing lands in the state, and the wide distribution of poisonous plants, their eradication, save in pastures or in certain restricted districts, seems like a hopeless undertaking. Plants that tend to grow more in patches, like the woody aster, monkshood, death camas and false hellebore, promise more in the way of extermination by the use of the grub hoe, than do loco, larkspur and lupine, which are more widely distributed. One instance came under observation in which all the loco weeds on a section of land, under fence, were removed by digging, and three years later the pasture was apparently as badly infested with loco weeds as before, much to the discouragement of the owner. The displacement of noxious weeds and poisonous plants by aggressive forage plants, has received some attention by the Montana Experiment Station and the Forestry Service. For this purpose, the smooth brome grass and the western wheat grass, or "bluejoint," have been considered the most promising. It will require several years at least and much patient endeavor to form a sod with smooth brome grass, sufficiently thick to replace larkspur, camas and loco weeds, which are indigenous and very persistent. The prospect for eradicating poisonous plants by this means is not very encouraging.

ALGAE: GREEN SCUM, GREEN SLIME, WATER MOSS

The algae are simple plants that do not bear leaves, stems, roots, and flowers. Their methods of reproduction are comparatively simple. They are common the world over, living in the water or in very moist situations. The green scum or slime so frequently observed upon the surface of pools, stagnant ponds, reservoirs, ditches, and streams is a growth of algae. Algae also sometimes form heavy growths at the bottom of the water, frequently being attached to stones, sticks, and mud. They are also commonly found in tanks and water troughs, and, in such places, may not only stop up inlet and outlet pipes, but render the water objectionable to stock, especially when decay sets in. Decayed algae have a peculiar pig-pen odor.

The common algae found in fresh waters are either blue-green or green in color. Many that occur in the salt water of the ocean are brown or red in color. When the green algae, the forms with which we are most familiar, begin to decay, they may change to brown or reddish-brown.

The individuals of some kinds of algae are microscopic, but when found in mass give a distinct color to the water in which they live. Small pools of water may become greenish in warm weather, and on inspection with the unaided eye one is not able to see the or-

ganisms causing this coloration. But microscopic examination reveals the presence of millions of small plants.

The question is often asked: Will the green scum found in the watering tank or trough, in water drunk by stock, render the water poisonous? Although algae may give water an objectionable appearance or odor, they do not render it poisonous either to stock or human beings. Furthermore, it is not at all probable that even decaying algae injure the water to the extent of making it poisonous.

However, on account of the objectionable odor that decomposing algae impart to water and on account of their tendency to close up drains and pipes, it is often highly desirable to get rid of them. Algae are now quite easily prevented from growing in water by treatment with copper sulphate.

Eradication.—Use 1 part of copper sulphate (blue vitriol) in 1 million parts of water. Practically, this treatment is best effected by placing a few pounds of the crystals of copper sulphate in a gunny sack, tying this behind a boat and rowing about the pond or reservoir. Fifteen pounds of copper sulphate to 1 million gallons of water is a practical proportion. In the case of a water trough, through which water is steadily running, a small sack of copper sulphate suspended near the inlet will suffice to kill all green scum. If the water in the trough is not freely running in and out, the suspension, in the water, of a small sack of blue vitriol for a short time now and then throughout the season, will keep green scum from collecting. The small quantities of sulphate that go into solution are harmful to the algae, but do not injure livestock or human beings.

FUNGI

The fungi are an immense group of plants that vary widely in shape, size, color, and habits of living. They do not have roots, stems, leaves, flowers, and seeds. They are rather simple in structure and methods of reproduction. Probably the best known fungi are the molds on bread, fruit, and cheese, the rusts and smuts of the cereals, the toadstools and mushrooms, the mildews, and the fungi causing such well-known diseases as blight in potato, alfalfa leaf spot, leaf spot of strawberry, potato scab, leaf spot of beet, wilt of flax, etc.

Some of the fungi work on the outside of the plant they infest, while others do their injury within. In most cases, the conspicuous part of the fungus is the spore-bearing stage.

Poisoning by fungi.—Many plants of this group are poisonous for animals. There is a disease which has been variously named by different investigators, practitioners and others, as food poisoning, forage poisoning, mold poisoning, blind stagger, sleepy stagger, cerebrospinal meningitis, etc., that has been known for a century at least and has caused widespread devastation among animals. The

so called "Kansas Horse Plague" has been quite generally attributed to forage poisoning.

Sporadic cases of this disease are very common in all parts of the United States and at all seasons of the year.

Symptoms.—The first symptoms noticed by the casual observer are depression, drooping of the head, closing of the eyes, difficulty in swallowing, staggering gait, walking in a circle and in some cases pushing the head against the manger or a post. Paralysis follows and the animal finally goes down, and dies within a few hours, or in some cases may live for several days.

Prevention.—The fact that an animal has had the disease does not protect it from a subsequent attack. It should be an absolute rule among farmers and stockmen to *never feed decayed, moldy or spoilt food to animals*. Moldy ensilage, decayed potatoes, carrots, sugar beets, musty hay, and moldy corn stalks are especially dangerous.

Prevention is difficult in those cases that occur on the open range or in grass pastures. The poisoning is presumably from fungi that develop on the grasses under certain climatic conditions. In these cases animals should be taken immediately from the pastures and fed hay that was cut the previous year or earlier in the season.

Treatment.—Many animals that would otherwise die may be saved by appropriate treatment. The services of a competent veterinarian should be sought without delay. Do not try to give any medicine by the mouth for the reason that the throat is paralyzed and the substances, especially if a fluid, will be liable to pass into the lungs and kill the animals. Hundreds of horses were killed in this way during the Kansas outbreak.

MILDEWS

There are two groups of mildews, the *Downy Mildews* and the *Powdery Mildews*. The downy mildews form a downy, white growth upon leaf, stem, and fruit surfaces. One of the most common downy mildews to be found in Colorado on cultivated plants is that growing on alfalfa. Many native plants are infested with these fungi.

The powdery mildews are parasitic fungi, very common on the leaves of many cultivated and wild plants. The growth at first has a cobwebby appearance; later, the leaf becomes powdery, due to the production of great numbers of reproductive spores. Still later in the season, fruiting bodies come on the infested plant; these are in the form of black dots, a little smaller than a pin head. Common powdery mildews are those found on the gooseberry fruit, peach, rose, peas, wild and cultivated grasses, and other forage plants. Moist meadows are frequently badly troubled with a powdery mildew. This may be observed to form a white, mealy coating on the leaves. Warm, moist weather favors the development of the mildews.

Poisoning by mildews.—According to Dr. Pammel in his "Manual of Poisonous Plants" catarrhal stomatitis (sore mouth) may be produced by eating fodder which has become infested with various

fungi including mildew. The extent to which the mildews are poisonous has never been determined but they are generally accused of causing inflammation of the digestive tract and other serious digestive disorders.

SMUT

This is a large group of well-known fungi. The best known are those occurring on the cereals. Among these may be mentioned corn smut, stinking smut or bunt and loose smut of wheat, loose and covered smuts of barley, loose and kernel smuts of oats, kernel and head smuts of sorghums. Besides these well-known smuts on cereals a number occur on native plants, including grasses and other forage plants. Among these may be mentioned the smut on brome grasses, barnyard grass, Indian millet, manna-grass, squirrel-tail grass, wild rye-grass, fescue-grass, hair-grass, slender wheat-grass, etc. Buffalo-grass and grama-grass, the two most abundant and important forage grasses of the Great Plains, are each infested with a smut. These smuts may become very abundant in seasons favorable to their growth. They are especially noticeable in spring and early summer. Hence it is seen that smuts, as a group, are widely spread throughout the state, occurring on both cultivated and wild plants.

Smuts are conspicuous on account of the black, dusty spore masses, which, as a rule, break out on the flowering heads, but also frequently on leaves and stems. A single smutted corn or sorghum plant may produce tremendous quantities of dry, black spores.

Poisoning by smuts.—It has been a common belief for many years that smuts are injurious to livestock. Feeding experiments, however, have demonstrated that no bad results follow from cattle eating any of the smuts. Of course, they may cause a sore throat or irritation of the throat when administered in large quantities, but the injury is not fatal. Furthermore, there seems to be no ill effects resulting from feeding siloed smutty grain or forage.

RUSTS

The rusts are an exceedingly large and widely distributed class of fungi. The best known are those on cereals. There are rusts on wheat, oats, barley, rye, and corn.

Any number of cultivated and native plants, many of which are grazed, is the home of rusts. Common forage grasses that are frequently rusted are timothy, orchard-grasses, fescue-grasses, brome-grasses, wheat-grasses, rye-grasses, marsh-grass, squirrel-tail, salt-grass, grama-grass, wire-grass, and many others; in fact there are but few grasses that are not infested more or less with some rust. There are also rusts on peas, vetches, beans, clover, alfalfa, and a great many of the herbaceous plants that may be eaten by stock. Hence it is readily seen that rusts are common everywhere and on a great variety of

plants. And it is quite certain that stock eat considerable quantities of the fungus in their grazing and feeding.

Injury from rusts.—Rusts no doubt cause considerable irritation of the mouth and the digestive organs and when eaten in large quantities give rise to a catarrhal condition or even severe inflammation. Rusty clover and alfalfa are especially objectionable. Rusts, as a group, are not poisonous.

MOLDS

Many fungi are known by the name of "mold." Well-known ones occur on fruit, bread, and cheese. A bluish-green moldy growth develops on hay, ensilage, fodder, and the kernels of corn, barley, and other cereals, usually when they are cured or stored under moist, warm, or poorly aired conditions.

Poisoning by molds.—Some of the molds are very poisonous and others are not. The inability to tell which molds are poisonous should make one cautious about feeding moldy foods of any kind. Poisoning by molds was discussed on a previous page under the subject of fungi.

ERGOT (*Claviceps purpurea*)

Ergot is a name applied to one stage of a fungus working in the heads of a number of grasses. The ergot stage is a purple-black, straight or horn-like hard structure about one-fourth to one-half inch long (fig. 1). It occupies the position of the grain in the head



Fig. 1.—Ergot: Note the black, horn-like bodies occupying the position of the grain. Ergot is shown here on six different grasses, cultivated rye at the left, the remainder native forage grasses.

of grass. This hard mass is not a degenerate kernel of grass, however. During the fore part of the growing season, the young and tender ovaries of the grass flower are infected with spores of the fungus, which later develops into the ergot stage. As a result of this infection, a fungus growth covers and penetrates the young grass ovary, finally replacing the latter entirely with fungal tissue. Minute spores are then produced in large numbers, and carried to other plants by means of insects and wind. In this way the disease spreads throughout the field. In the latter part of the summer the soft fungous mass in the head of grass is replaced by the characteristic hard, black structure, commonly known as ergot (fig. 1). This is the structure by means of which the fungus lives over the winter. The black ergot masses vary in size and shape, depending upon the plant attached. They are the largest on rye.

Ergot develops upon a number of grasses. Chief of these is cultivated rye (*Secale cereale*) and various species of wild rye (*Elymus*). It also occurs on several wheat-grasses (*Agropyron*), a number of meadow grasses (*Poa*), timothy (*Phleum pratense*), a reed canary-grass (*Phalaris arundinacea*), prairie June-grass (*Koeleria cristata*), and several other grasses.

Ergot is widely distributed throughout this country and Europe. It does but little injury to the grass upon which it is living, but is often the cause of serious troubles in livestock.

Ergotism.—Ergotism is the disease caused from eating grasses that contain ergot. Cattle are most often affected. The disease makes its appearance most often during the winter and spring but may appear at any time.

Symptoms.—Two distinct types of the disease are recognized, namely, spasmodic and gangrenous. There are serious digestive disturbances in both types of the disease.

In the spasmodic form there are spasmodic contractions of the muscles, numbness of the extremities, tremblings, convulsions and delirium. In the gangrenous form of ergotism there is, as a result of prolonged constriction of the blood vessels, especially of the extremities, a decreased amount of blood to the parts, and in some cases the circulation is completely obstructed. When the circulation is obstructed dry gangrene follows and there is sloughing of the tips of the ears, tail, hair, and even the feet may come off as far up as the canon bones. Cold weather of course helps to make conditions worse.

Treatment.—In the first place remove the cause. Examine the hay for the black ergot bodies which grow in place of the kernels of grain in the heads. Treatment is not very satisfactory in well established cases. Tannic acid is the best chemical antidote and its effect is upon the poisons that are not yet absorbed into the circulation. Chloral is probably the most satisfactory physiological antidote. Animals affected with ergotism should be kept warm and treatment should be directed to meet the conditions as they arise.

“TOADSTOOLS” AND “MUSHROOMS” (*Fleshy Fungi*)

There are a great many different sorts of fleshy fungi that are called “toadstools” and “mushrooms,” depending upon whether they are considered poisonous or edible. Although a number of these fungi poison human beings, it is doubtful if stock ever eat them.

BLACK SPOT OF GRASSES (*Phyllachora graminis*)

In late summer and fall, there appear on the leaves of several of our forage grasses, jet black spots, especially noticeable along the veins. These spots are very small, scarcely larger than a pin-head,



Fig. 2.—Four different lichens

and occur on both surfaces of the leaf, although more abundant on the upper. In Colorado, “black spot” is found on several different forage grasses. It may be the cause of a stomach inflammation in stock.

LICHENS

The most common lichens (fig. 2) are those forming crust-like coverings on the surface of rocks, or tree trunks, or on the ground. Some are raised considerably above the surface upon which they grow,



Figs. 4 - 5.—Brake-fern (*Pteridium aquilinum*): 4, single leaf of brake-fern; 5, single pinna of leaf of brake-fern, showing the spore masses on the under surface.

and are leaf-like. There is a form of lichen in our mountains which hangs in gray-green moss-like masses from the branches of the evergreens. Lichens have a great range of color: orange, yellow, green, gray, brown, and black. They are composed of certain algae and fungi growing in intimate relationship. Lichens, as a group, with stand drying very well, and have remarkable powers of recovery when moisture becomes available.

None of the lichens are known to poison stock. It is quite likely that some of the leafy sorts are eaten to a slight extent.

MOSSES

Mosses are familiar to all. They are not as abundant under the dry atmospheric conditions of Colorado as in moister sections of our country. They are the best developed in the mountains, especially along streams and in shaded situations. None of the mosses are known to be, or suspected of being, poisonous to stock.

FERNS

Colorado does not possess a large variety of ferns; furthermore, they do not grow in such luxuriance here, as in the damp, moist woods of the eastern states.

Ferns have underground stems that run horizontal to the soil surface. They spread by means of these stems, and also by means of spores. The spores are formed on the under side or margin of the frond (leaf). These spores occur in reddish-brown masses (fig. 4).

The only fern in Colorado that is suspected of being poisonous to stock is the brake-fern (*Pteridium aquilinum*) (fig. 5). This plant has widely-spreading, blackish rootstocks. The leaves are two to three feet long, and divide into three main divisions, each of which is again subdivided.

EQUISETUM: HORSETAIL, SCOURING RUSH, JOINTED GRASS

There are several species of *Equisetum* growing within Colorado. The two most common ones are the Common Horsetail (*Equisetum arvense*), and the Smooth Scouring Rush (*Equisetum laevigatum*). Both are rush-like perennials from underground rootstocks. They have rough, jointed stems that are closed at the joints. The stems are marked with a number of grooves that run lengthwise. At the joints are small, pointed leaf-like structures, the sheaths. All horsetails and scouring-rushes have harsh, rough stems, due to deposits of silica (sand) within.

The common horsetail (figs. 6 and 7) (*Equisetum arvense*) dies down to the ground each year. It has two kinds of stems. In the early spring there are sent up from the underground rootstocks, simple, unbranched jointed stems, which bear a spore-bearing cone-shaped organ at the top (fig. 6). These die down after spore production, and are followed by slender, solid, 4-cornered stems that send out numerous branches at the joints (fig. 7). The common horsetail is found throughout the state, from the plains up to as high



Figs. 6 - 7.—Horsetail or scouring rush; 6, early spring stems arising from underground stem; note fruiting cones; 7, branching form which appears later than the preceding.

as 10,000 feet. It commonly grows in sandy places, along railways, roadsides, and in low meadows. In meadows, it may become so abundant as to injure the hay. It is here that it gives the greatest amount of trouble.

The smooth scouring rush (*Equisetum laevigatum*) is ever-green. The stems are stout and often reach a height of 5 feet. They may be branched or unbranched. This plant grows all over

Colorado from low to high altitudes. It is also found in low ground, particularly in a clay soil.

Poisoning by Equisetum.—*Equisetum* is so abundant that most people do not suspect that it is poisonous. It is found in much of the native hay of Colorado. Many reports have come to the Experiment Station of serious poisoning of animals that could only be attributed to horsetail. We have never had reports of animals other than horses being affected.

Symptoms.—The first evidence of the trouble is more or less unthriftiness and in most cases diarrhoea. The horse appears thin and the muscles wasted. After two to five weeks, according to the amount of horsetail in the hay, the horse begins to lose control of its limbs, sways and staggers, although its eyes look bright and the appetite is normal. After the muscular symptoms become pronounced the horse will refuse to lie down and if it gets down will struggle violently to get to its feet. The extremities are cold, and horses that are affected from eating *Equisetum* suffer greatly from the cold in the winter time. Young horses develop the symptoms much quicker than older ones. Some claim that horses develop a depraved appetite for the weed.

Treatment.—Stop feeding the *Equisetum* hay and give a quart of raw linseed oil as a physic. After the physic has operated give a teaspoonful of powdered nux vomica, mixed with the feeds of grain, three times a day. If the horse becomes very weak, he should be supported by slings. These cases, if given prompt attention and an appropriate treatment, will recover in most instances.

EVERGREENS (*Conifers*)

The pines, spruces, firs, junipers and cedars are widely distributed over Colorado. They have not been known to poison stock.

CAT-TAIL (*Typha latifolia*)

This common plant, found in marshes at lower altitudes in Colorado, is suspected of being poisonous.

GRASSES

A number of grasses are known to poison stock, while others injure them mechanically by means of their sharp beards or bristles.

Grasses are closely related to and frequently mistaken for sedges. Sedges, however, have solid stems, usually 3-cornered. They prefer, as a rule, moister situations than grasses.

POISONOUS GRASSES

JOHNSON GRASS (*Andropogon halapensis*)

This is a perennial from rootstocks. The plant is from 3 to 5 feet tall. The leaves are broad, flat and smooth. The inflorescence or flowering head often measures 1 foot or more in length, and branches profusely. The spikelets are in pairs; one of these has a short stalk, the other is without. The spikelets are covered with long, soft hairs, and are often purplish in color when mature. A beard may be present or absent.

Johnson grass has been reported from several localities in Colorado. In some places it is cultivated, and from such it may escape and become a weed.

Johnson grass is undoubtedly poisonous under certain conditions. Discussion of this subject will be found under the head of Sorghums.

SORGHUMS (*Andropogon sorghum*)

The sorghums comprise a large and well-known group of plants that are used both for their grain, and as hay and fodder. Under the name "sorghum" are included sweet sorghum or sorgo, milo, durra, kafir, broom corn, kaoliang, shallu, feterita, and Sudan grass. All are annual plants, ranging in height from 3 to 15 feet. The "heads" vary considerably in size, shape and color.

Poisoning by sorghums.—A large number of plants are known to be poisonous from the presence of prussic or hydrocyanic acid. This acid is known to be one of the most deadly poisons, and it results from the presence in the plant of what is known as a glucoside which must be acted upon by a ferment. The most important and best known of all the glucosides is amygdalin. A large number and a great variety of plants contain a hydrocyanic acid producing glucoside. Plants that are conspicuous in this class are sorghum, kafir corn, Johnson grass and wild cherry.

Conditions under which poisoning may occur.—The second growth of sorghum is generally accused of being the more dangerous, but in the late summer when the second growth appears the entire plant contains poison. Kafir corn is the least dangerous when grown luxuriantly under irrigation or bountiful rainfall. The conditions which prevail in the arid districts of Colorado are ideal for growing kafir corn that is most dangerous. When kafir corn has made a stunted growth, and in the fall for two or three weeks before frost, the most poisoning occurs. After it has been cured from cutting or frost, it has never been known to kill animals, unless it be later demonstrated that hydrocyanic acid is a causative factor in "Corn Stalk Disease."

The leaves of several species of wild cherry are very deadly to cattle. The special condition under which wild cherry poisons animals, is when the leaves are partially wilted.

The poison in question has been found in a great number of both native and domesticated plants and it is quite possible that in many cases where a large number of animals have died mysteriously, without the presence of either infection or any known poisonous plant, that some plant capable of developing prussic acid is responsible.

Symptoms.—A few mouthfuls of highly poisonous kafir corn taken on an empty stomach have been known to kill a cow in ten minutes. At Brighton, Colorado, thirty-two cows, after being kept in the corral over night, were turned into a field of kafir corn, of not over two acres, that had been grown above the ditch, and twenty-one of them were dead in half an hour and four of the others were badly affected.* The first thing noticed in a poisoned animal is giddiness and difficult breathing with spasmodic defecation and micturation.

* Bulletin No. 77, Nebraska Experiment Station.

The pulse is slow and the pupils dilated. In fatal cases this is followed by spasms, general paralysis, delirium and death. In subacute cases the above symptoms will appear in a milder form and the animal may regain consciousness and be on its feet in an hour or two.

Treatment.—Farmers should know the conditions under which the plants mentioned are liable to kill their animals, and take no chances. Acute cases are so rapidly fatal that the animal is often dead before remedial measures can be adopted. In case of poisoning by prussic acid in connection with forage, however, the symptoms usually do not develop so quickly and some assistance may be given. Inhalation of ammonia and throwing alternately cold and warm water over the head and neck have been advised. Hypodermic injections of atropine sulphate to stimulate the heart and respiration are indicated. The chemical antidote (which must be given before the poison is absorbed) is a mixture of ferrous and ferric salt, administered with magnesia or potassium carbonate in solution.

MILLETS

The proso or broom corn millet, foxtail millets and pearl millet are the principal ones grown. The foxtail millets (*Setaria italica*) are divided into a number of types, chief of which are the Hungarian, German, Common, Golden Wonder, and Siberian. All are annual.

MECHANICALLY INJURIOUS GRASSES

SAND-BUR (*Cenchrus tribuloides*)

The common sand-bur (fig. 8) is an annual grass with flat leaves. The long stems may be prostrate on the ground for a part of their length. The characteristic feature of the plant is the spiny structure surrounding the spikelet. As a consequence, there is formed a spiny bur, the spines being stout and barbed. There are as many as 20 burs in an inflorescence. The seed matures from July to September. Sand-bur is found growing in sandy soil, as a rule. It occurs throughout Colorado, at lower altitudes.

POVERTY-GRASS, WIRE-GRASS, THREE-AWNED-GRASS (*Aristida longiseta*)

This is a tufted silvery-colored perennial with numerous rolled, wire-like leaves at the base of the plant. Its common height is about 1 foot. There are some varieties that are much more robust, however. The flowering head is 4 to 8 inches long. The spikelets are small and 1-flowered. The grain is tipped by three beards or awns (fig. 9), thus suggesting the common name "three-awned-grass." The lower end of the mature seed is very sharp-pointed.

Wire-grass is one of the chief grasses of the Great Plains. In certain places in eastern Colorado it forms an extensive growth. It is also found on dry hills, up to an altitude of 9,000 feet.

FEATHER-GRASS, PORCUPINE-GRASS, OAT-GRASS (*Stipa*)

There are a number of different *Stipas* growing in Colorado, all of which are tufted perennials. The leaves are usually rolled. The inflorescence branches. Each spikelet produces one seed, which falls at maturity from the flowering head. Each grain bears a long beard



Figs. 8 - 12.—Mechanically injurious grasses: 8. sand-bur; 9, grain of three-awned grass; 10, grain of porcupine grain showing long, twisted beard; 11, spikelets of downy brome-grass; 12, triplet of spikelets of squirrel-tail grass.

(fig. 10), which is twisted at the base, where it joins the body of grain, and is more or less bent. The base of the grain is very sharp-pointed, and the small barbs on it point upward. Hence, the grain may work inward easily, but on account of the direction of the barbs, it is impossible for it to work outward, or to be pulled out easily. It matures its seed from July 15 to August 15. The mature seed immediately drops to the ground.

The Western Stipa, or Needle Grass (*Stipa comata*) bears beards that reach a length of 4 to 6 inches. This grass is abundant in sandy soil throughout the plains and foot-hill regions. There are a number of other species of Stipa, which differ from Needle Grass in having beards usually less than 2 inches long. In these, also, the beards are twisted and bent, and the grain-base is sharp-pointed, and may in some instances work mechanical injury to stock. One of the very common short-bearded Stipas is Vasey's Stipa-Grass (*Stipa vaseyi*). It is particularly abundant in the foot-hills. It grows from 3 to 6 feet high and bears an inflorescence 8 to 18 inches long. The beard on the grain is usually bent twice, and twisted to the second bend.

WILD OATS (*Avena fatua*)

This is an annual plant much resembling ordinary cultivated oats. It has long, slender stems, and hence it usually stands above cultivated oats. It is distinguished further from cultivated sort by its strongly bent beard, and the long, reddish-brown hairs at the base of the grain. The seeds ripen earlier than those of wheat and oats. The seed is barbed.

DOWNY BROME-GRASS, AWNED BROME-GRASS, SLENDER CHESS (*Bromus tectorum*)

This brome-grass is an annual. It stands 1 to 2 feet tall. The leaves are soft hairy. The flowering head has slender, drooping branches. The spikelets (fig. 11) are on very thin stalks; they bear a number of seeds. They may become purplish at maturity. Each seed has an awn which equals the seed itself in length.

This plant is becoming increasingly abundant in Colorado, occurring in fields, along roadsides and in waste places. In many localities it has made its first appearance the last year or two. Up to now it has been seen only at lower altitudes.

The beards on the seeds frequently cause serious injury to stock. The bearded seeds work in under the teeth causing inflammation, and in some instances a loss of the teeth.

WILD BARLEY, SQUIRREL-TAIL GRASS (*Hordeum jubatum*)

In the West, this common grass is an annual or short-lived perennial. It grows from 6 inches to 2½ feet high, in bunches. The head is 4 inches long or less, pale green, often purplish. The beards on the seed-bearing, and sterile flowers are long, and the flowers are surrounded by long beard-like glumes so that the whole head is covered with long bristles (fig. 12) that are rough and upwardly barbed. The head breaks up at maturity and the parts are scattered broadcast.

Squirrel-tail grass is common, in alkaline soils, about ponds, lakes and reservoirs, along irrigating ditches and streams, in mead-

ows, and in fields wet from seepage. It is a common sight in Colorado to see ponds and lakes surrounded by a well-marked zone of squirrel-tail. Squirrel-tail grows over the entire state up to as high as 9,000 feet.

The plant is not only troublesome as a weed in cultivated fields but it is a great source of injury to stock. Although it may be eaten by all classes of stock when young, when mature the awns have very injurious effects.

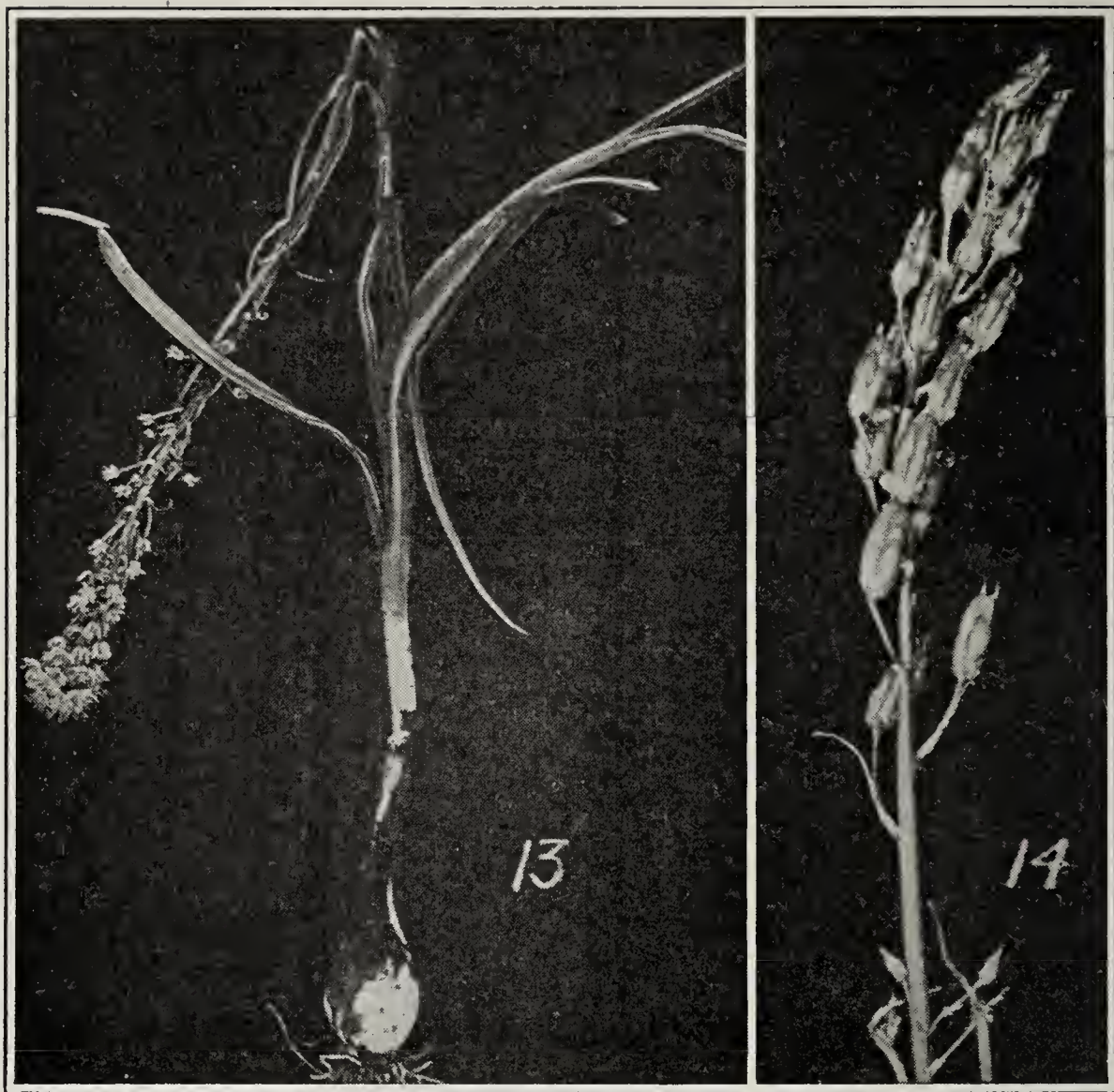
Wind is the chief agent in the dissemination of the seed, but in the irrigated sections, its spread by water is common. Plants growing on the banks of irrigating ditches drop their seed into the running water, which carries them to fields where they are distributed over the land. Every precaution should be made to prevent the seeding of squirrel-tail along ditches. If possible, mow the infested area several times during the season to prevent seeding.

Mechanical injury from grasses.—As a group, the mechanically injurious grasses frequently inflict serious wounds. The beards may bore into the skin, or the mucous membrane of the mouth, causing ulcerations. They have been known to bore into the intestines, causing fatal inflammation. The beards of *Stipa* grasses are reported as injuring the eyes of sheep. Sheep have also been known to die from body wounds inflicted by the beards of grasses. In some instances the beards work in under the teeth causing inflammation and the formation of pus. As a result, the animal may lose its teeth. Ulcerations of the jaw bones sometimes follow.

DEATH CAMAS (*Zygadenus*)

There are several species of death camas growing within Colorado. The following description is made general enough to include all of them. There is no attempt to distinguish between the different sorts, for such a distinction is of no advantage, in this case, to the practical man.

The plants are perennial from a bulb (fig. 13). This bulb is made up of a series of layers, like the onion, the outer ones being thin, blackish-brown, and peeling off, showing the white-colored layers beneath. The bulbs are, as a rule, very deep-seated, so much so that it is difficult to get them up without breaking the stem. An average size bulb is about 1 to 1½ inches long and ½ to 1 inch thick. It tapers above into the solid stem. A tuft of roots arises from the under side. Plants vary in height from 8 inches to 2 feet. They are smooth throughout, no hairs or bristles being present. The leaves are long, narrow, and more or less folded along the midrib; they resemble those of the onion. There are usually 6 to 7 fully formed leaves on a plant. The flowers are at the tip of the stem, in an inflorescence 3 to 10 inches long; they are greenish-yellow or whitish in color. Each flower (fig. 15) has 6 segments, about ½ inch long; at the base of each segment on the inner surface is a golden yellow, shining gland, which may be seen without the aid of a hand lens. The lowermost flowers mature their fruit first, in fact there may be flowers



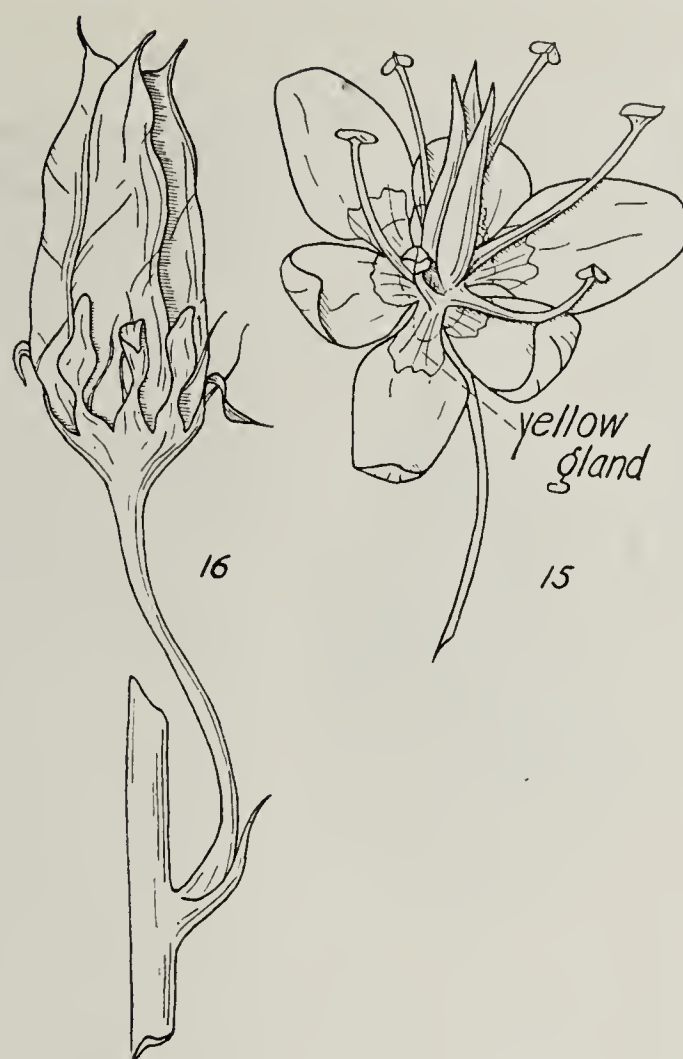
Figs. 13 - 14.—Death camas: 13, entire plant; 14, fruiting stalk.

and fruit in the same flowering group. The fruit (figs. 14 and 16) is usually 3-parted, the separate parts united except at the very tip.

Considering the different species found in Colorado, death camas occurs throughout the whole state, from low to high altitudes. There is some evidence that plants growing at high altitudes belong to a species that does not contain as much of the poisonous principle as plants at lower elevations.

Death camas makes its appearance in the spring and early summer. At lower altitudes the flowers are in bloom during June. During maturing of fruit, the flower stalk may lengthen considerably. It is abundant in the foot-hills, sometimes on stony hillsides, also on sandy plains, but more abundant in moist, sandy swales. As a rule they do not form a close stand; the individual plants are rather scattered.

Death camas may be confused sometimes with several other plants. One of these is the white hellebore (*Veratrum speciosum*) (fig. 17). It has rootstocks instead of bulbs, the leaves are large and oval and clasp the stem, and there are no glands at the base of the petals and sepals of the flower. Another is the spiderwort (*Tradescantia*), which has leaves very much like those of death camas, but no bulb; the flowers are blue and much larger. Another is the sand-lily (*Leucocrinum*), a low plant, close to the ground, with large white

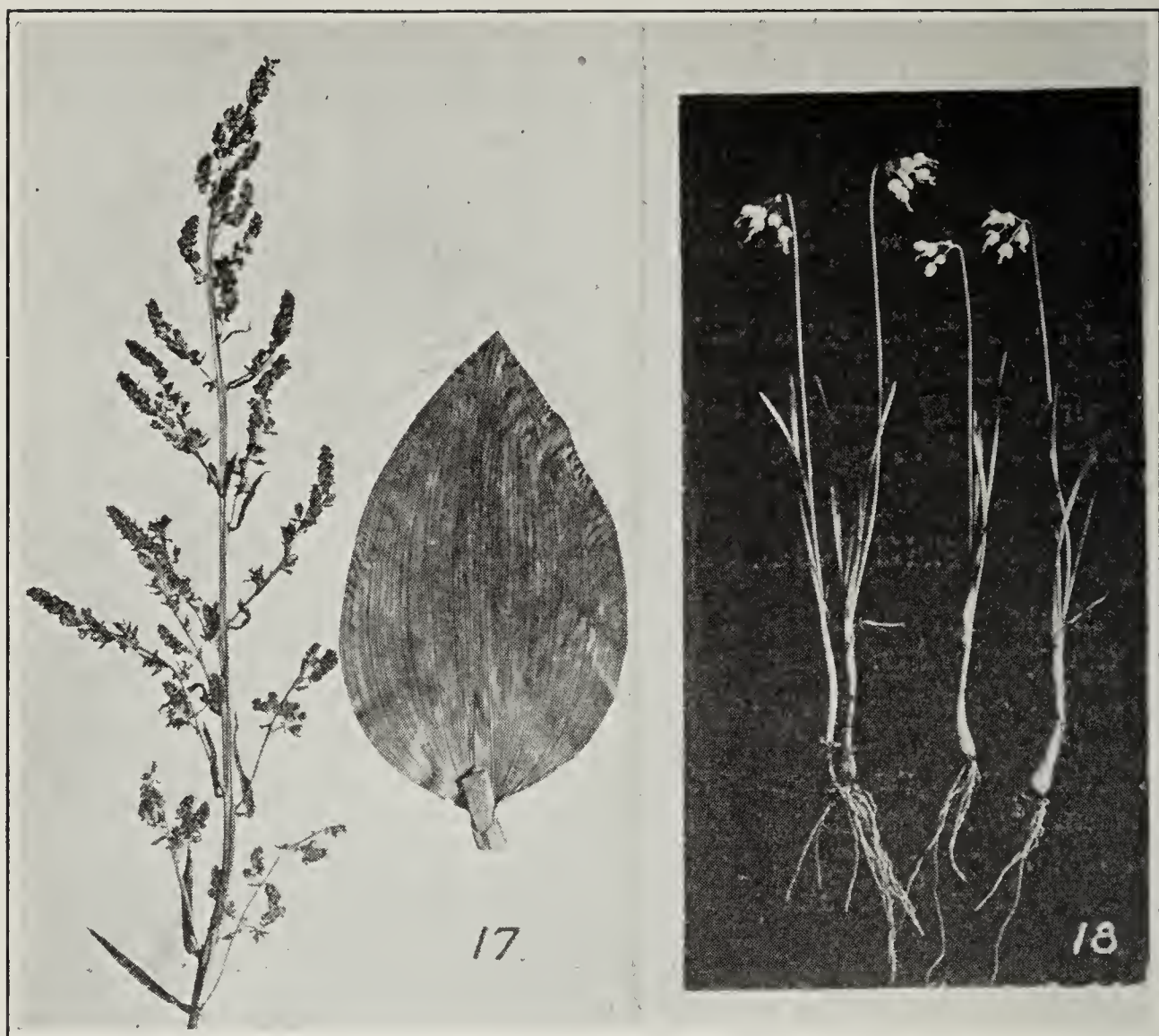


Figs. 15 - 16.—Death camas: 15, single flower showing 3 sepals, 3 petals, 6 stamens, 1 pistil, and yellow glands; 16, single pod.

lily-like flowers. The wild onions, of which there are a number of species, are most frequently mistaken for death camas. They have bulbs and leaves that are similar to those of death camas. However, the odor of the wild onion should be sufficient to distinguish it from the death camas. The flowers are arranged quite differently in the onion as may be seen readily by comparing figs. 13 and 18. Occasionally, the mariposa lily (*Calochortus*) is mistaken for death camas. In this, the underground stem is a corm, that is, a solid structure, not made up of layers. Furthermore the flowers are few in number, large, and showy.

Symptoms of poisoning.—The symptoms of poisoning by camas are quite characteristic and one should be able to recognize these cases with a considerable degree of certainty. At first the animal is uneasy, and an irregularity of the muscular movements of the body is apparent. This is followed by complete loss of muscular control, rapid and difficult breathing, spasms and a frequent but weak pulse. The one condition that especially characterizes poisoning by death camas is the complete muscular paralysis without loss of consciousness.

Preventive and remedial measures.—There is only one way to prevent poisoning by death camas and that is to keep animals away from it. It is then of first importance that stockmen be able to identify the plant. It is first seen in the spring about the same time as the first green grass and dries up and disappears in middle summer. Its close resemblance to wild onion will help some in its identification.



Figs. 17 - 18.—17, leaf and flowering group of white hellebore; 18, wild onion or garlic, often mistaken for death camas.

Treatment.—The treatment that has given the best results is potassium permanganate. Chestnut and Wilcox report, as a result of their experiments, that it is effective both as a chemical and physiological antidote. For sheep, three to six grains, according to the size and age of the animal, of potassium permanganate and an equal weight of aluminium sulphate are dissolved in at least a pint of water and given at one dose by drench. Twenty grains of each dissolved in a quart of water constitute a dose for an average sized horse, and thirty to fifty for cattle.

It is very important that all of the potassium permanganate be dissolved, otherwise flakes may adhere to the walls of the throat or stomach, and cause intense irritation. Some stockmen make a practice of carrying this antidote in their saddlebags, ready for immediate use, during the spring months when there is the greatest danger of poisoning from camas. This practice is to be recommended since the antidote is equally effective for poisoning by larkspur, and larkspur and camas are most dangerous at about the same time in the early spring months.

WHITE HELLEBORE, FALSE HELLEBORE

(Veratrum speciosum)

This perennial (fig. 17), from a thick rootstock, grows from 2 to 7 feet high. The leaves are large, broad, and bear prominent veins, running parallel. The inflorescence may be over a foot long. The branches of the inflorescence are directed upward, and each has a long, narrow leaf at its juncture with the main stem. The inflorescence is covered with soft, white hairs. The flowers are whitish, each has 3 sepals, 3 petals, 6 stamens and a single pistil. The plant is not abundant in Colorado. It has been observed in a few localities, chiefly in the western half of the state. It occurs from 6,500 to 12,500 feet altitude. It prefers moist soil, such as is found along streams and in meadows.

Poisoning by white hellebore.—The swamp hellebore is not relished by animals, since it is acrid and bitter, but some cases of poisoning are reported. The seeds have been eaten by chickens with fatal results and a case is reported by Prof. Chestnut in which all of the members of a household were poisoned by eating the young leaves, mistaking them for marsh marigold. The root is said to have been used by the Indians in making snuff.

Symptoms.—Several poisonous substances are found in hellebore. Veratrin, which may be separated into several poisonous bases, causes extreme depression of the heart and respiration and general paralysis. The poisoned animal is first seen drooling saliva, vomiting or attempting to vomit, with colicky pains, shallow breathing; the skin becomes cold and clammy and there are muscular tremors and in fatal cases the animal dies in convulsions.

Treatment.—This consists in giving tannic acid as a chemical antidote with alcohol, strychnin and atropin to support the heart and respiration. Raw linseed oil may be given to relieve the local irritation and laudinum or morphine to relieve the pain.

SCRUB OAK (*Quercus*)

There are a number of species of scrub oak in Colorado. They are all small trees or shrubs, their common height being 10 to 15 feet. As a rule they grow in rather dense clumps. Scrub oak in Colorado is found in the foothills and mountains of the western slope, and as far north on the eastern slope as an east-west line about midway between Castle Rock and Denver.

Scrub oak is considered poisonous by many stockmen. They will take the pains to keep their stock from the oak thicket. It is very likely that most cases of poisoning resulting from cattle grazing in scrub oak thickets are due to larkspur which grows therein.

GREASEWOOD (*Sarcobatus vermiculatus*)

The common greasewood of the West is a shrub, 2 to 8 feet high. Its numerous branches are very stiff and rigid, and frequently somewhat spiny; the bark is smooth and white. The leaves are thick.

narrow, 1 to 2 inches long, and pale green in color. The flowers are small, inconspicuous and greenish.

Greasewood is characteristic of dry, alkali flats. It is distributed throughout the state, chiefly at lower elevations.

It is likely to be confused with several other shrubs: Winter fat or winter sage (*Eurotia lanata*) is a low shrub, coated with a mat of white, woolly hairs which may become reddish-brown. The common shrubby salt-bushes (*Atriplex canescens* and *Atriplex confertifolia*) are somewhat rigid or spinescent shrubs with smooth, white bark, much resembling greasewood. The leaves of the salt-bushes, however, are covered with minute scales, which give them a characteristic scurfy appearance. Those of greasewood are smooth. Furthermore, the leaves of the two salt-bushes given above are not long and slender, as in greasewood, but rather narrowly oblong in one, and oval in the other. The spiny Grayia (*Grayia spinosa*) also has mealy or scurfy leaves. The shrubby species of rabbit brush (*Chrysothamnus*) may be distinguished from greasewood by their flowers, which resemble those of goldenrod.

Greasewood is considered a forage plant, but is strongly suspected of being poisonous at times. Prof. Chestnut reports on this plant as follows: "A correspondent in New Mexico states that on one occasion he counted as many as one hundred sheep that had been killed by eating the leaves of this plant. It is claimed that cows are not affected by eating it at any time and that sheep can eat it quite freely in winter. Death is perhaps due more to the bloating effect than to any poisonous substance which the plant contains."



Fig. 19.—Cow-herb, cow cockle, wheat cockle (*Saponaria vaccaria*).

RUSSIAN THISTLE (*Salsola pestifer*)

The Russian Thistle is so well known that a description is unnecessary. In Prof. Pammel's Manual of Poisonous Plants is found the following: "The sharp spines on the plants not only irritate and worry both horses and men but often, by breaking under the skin, cause festering sores on the horses' legs, so that in many localities it has been found necessary to protect them with high boots or leggings."

COW-HERB, COW COCKLE, WHEAT COCKLE
(*Saponaria vaccaria*)

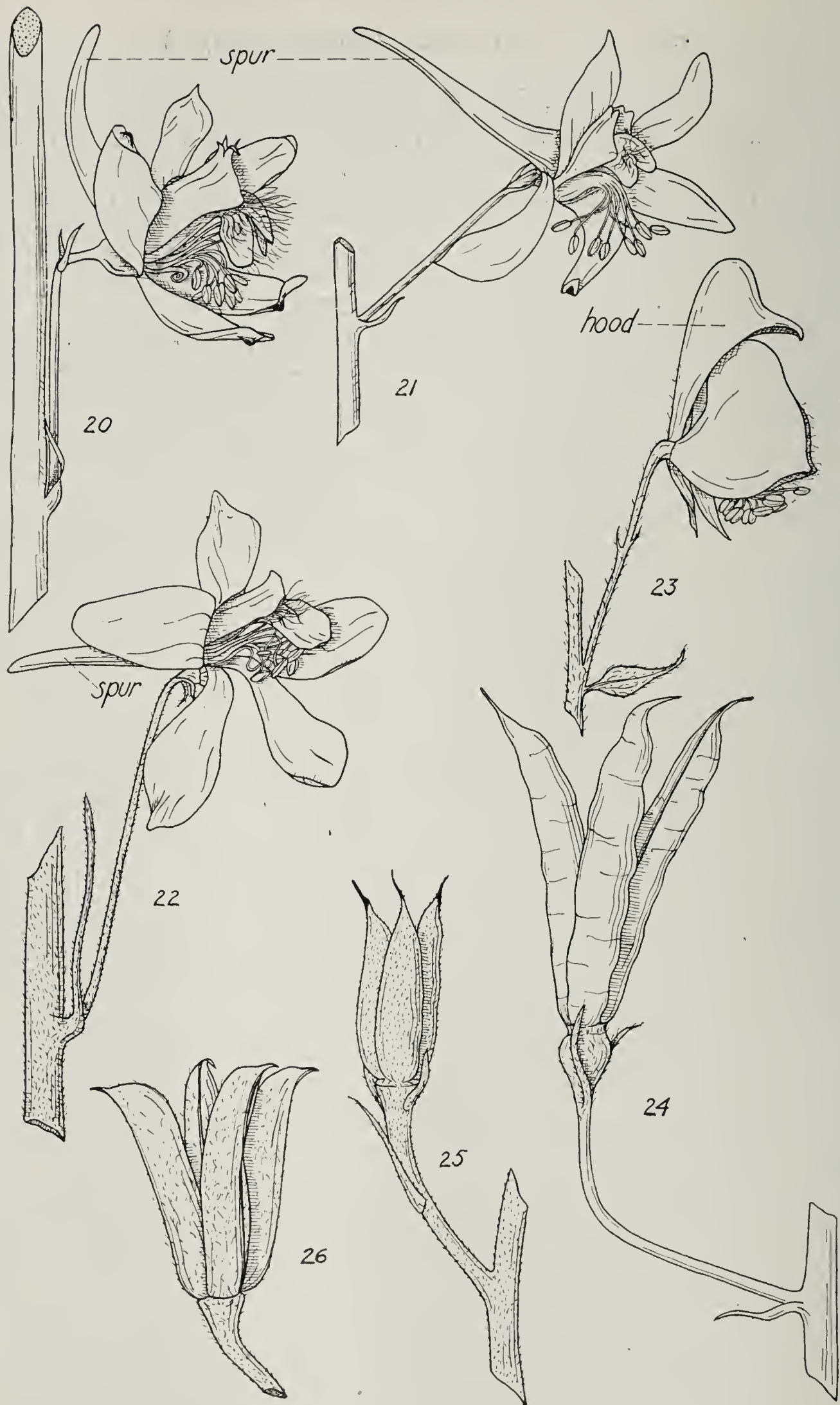
A smooth, branching annual plant (fig. 19) 8 to 16 inches tall. The leaves are opposite and lance-shaped. The flowers are a beautiful pink, in open clusters at the top of the plant. The calyx is 5-angled, and much enlarged in the fruit. The plant is a pest in some sections of the state, particularly in grain fields. It is found mostly at low altitudes.

The seeds of Cow Cockle are often found in wheat screenings, and are known to be poisonous. Prof. Pammel says: "According to Sohn it contains the substance *saponin*, a neutral, sharp, amorphous substance, having a burning taste and producing a violent sensation. The toxic substance is partially removed by baking." Saponin-like bodies are also found in the common plant known as "bouncing bet" and corn cockle.

LARKSPUR (*Delphinium*)

As a group, the larkspurs are easily recognized by the single long "spur" (figs. 20, 21, 22) of the flower. A single sepal of the flower is prolonged into a spur, and encloses two petals which are likewise extended. Larkspurs may be distinguished from aconite or monkshood, which they closely resemble, by the form of the flower. In aconite or monkshood the upper sepal, instead of being spurred, as in larkspur, is enlarged and has the appearance of a hood (fig. 23) over the other flower parts, hence the name monkshood. These differences are brought out in the drawings.

A number of native plants are often mistaken for larkspur, especially in the young stage. Chief of these is the wild geranium, of which there are several species within our borders. There are two small leaves (stipules) (fig. 30) at the base of the geranium leaf-stalk; these are absent in larkspur. The false mallow (fig. 31) (*Malvastrum coccineum*), when young, may also be mistaken for larkspur. Its leaves are coated with hairs that are in star-shaped groups (fig. 32). The leaves of the common spring anemone (fig. 34) (*Pulsatilla hirsutissima*) with lavender flowers, are much more divided and in a fashion different from those of larkspur. The wind flower (fig. 33) (*Anemone*) has leaves quite similar in shape to those of larkspur but the hairs are longer and more spreading. Both the common spring anemone and the wind flower have a characteristic group of leaves (involucre) on the flowering stem (see fig. 36). In fig 35 is shown the highly divided leaf of Virgin's Bower (*Clematis douglasii*) which may be mistaken at times for that of one of the larkspurs.



Figs. 20 - 26.—Larkspurs and aconite: 20, flower of Penhard's larkspur, note the erect flower stalk and spur; 21, flower of Nelson's larkspur; 22, flower of Geyer's larkspur; 23, flower of aconite; note the "hood"; 24, fruit of Nelson's larkspur; 25, fruit of Geyer's larkspur; 26, fruit of aconite.

The stockman should thoroughly familiarize himself with the appearance of young larkspur plants.

There are a number of species of larkspur growing in Colorado, the principal ones being as follows: purple, or Nelson's larkspur (*Delphinium nelsonii*), Geyer's larkspur (*Delphinium geyeri*), Penhard's larkspur (*Delphinium carolinianum penhardii*), subalpine larkspur (*Delphinium subalpinum*), and tall larkspur (*Delphinium glaucescens*).

Purple, or Nelson's Larkspur (*Delphinium nelsonii*).—The easily detachable cluster of thickened tuberous roots (fig. 38) is characteristic of this species. The plant (figs. 27 and 37) rarely exceeds 2 feet in height; about 1 foot is its common height. The leaves are divided into a large number of narrow segments. The flowers are blue, the two petals, not prolonged as spurs, each have a cobwebby tuft of white hairs in the center of the broad blade, on the outer surface. The fruit (fig. 24) may be smooth or hairy.

This species is the earliest of the larkspurs. It may be seen in bloom as early as April 20 at low altitudes. In the foothills it is usually past blooming by June 1.

Its altitudinal distribution is from 4,000 to 10,000 feet. It is found all over the state within these limits.

Geyer's Larkspur (*Delphinium geyeri*) (figs. 28 and 40).—This is a taller plant than the preceding, ranging in height from 10 inches to over 2 feet. The root is thickened and somewhat woody. There is a cluster of thick, dull-green leaves at the base of the plant; they are cut into numerous long, narrow segments, each segment being tipped with a white hardened point. The flowers are blue.

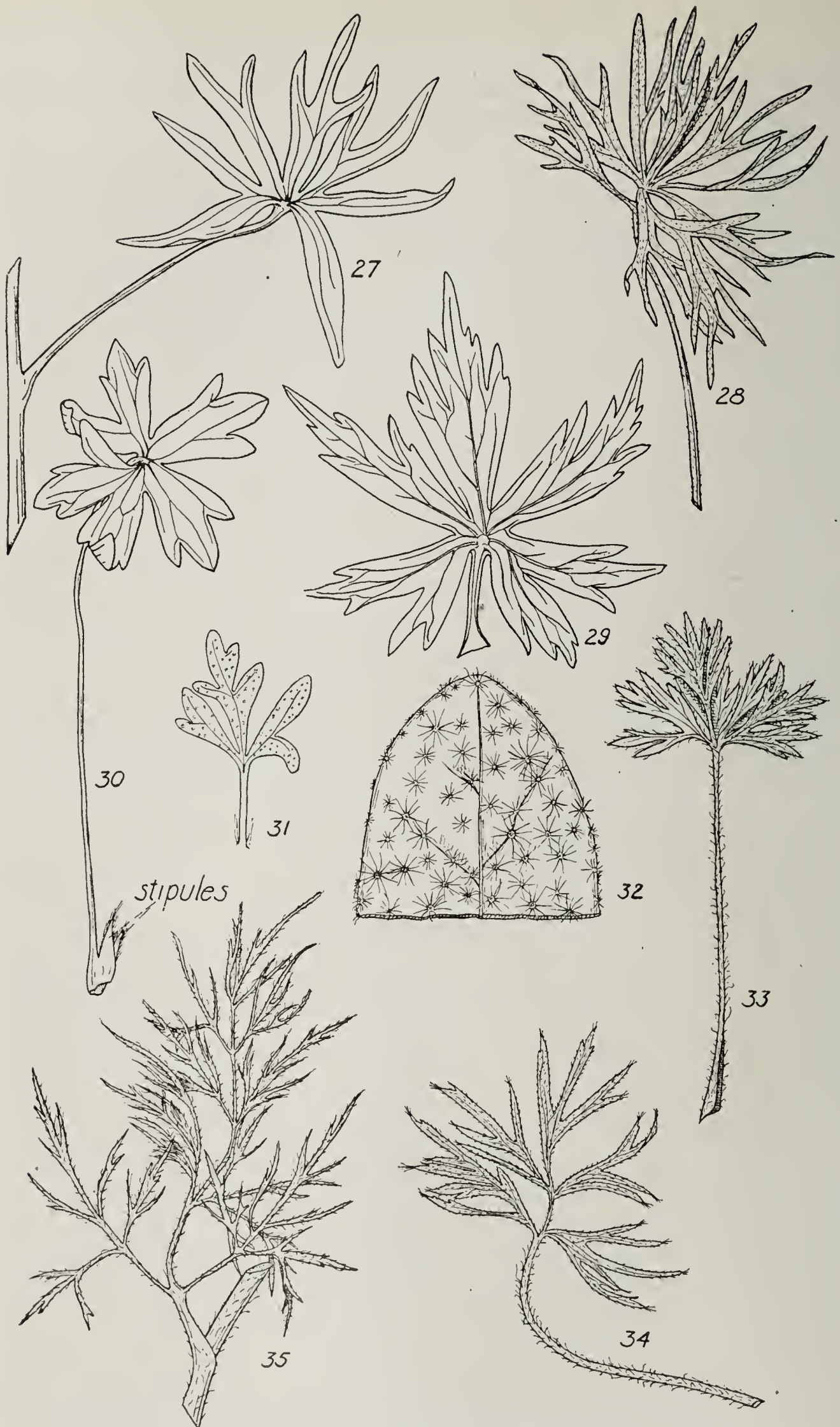
This larkspur is a plant of low altitudes, seldom growing above 7,000 feet. It blooms during the first part of July.

Penhard's Larkspur (*Delphinium carolinianum penhardii*).—(fig. 39). This species grows to about the same height as the preceding, and may often be found alongside it, occupying the same sort of habitat, and in bloom at the same time. The flowers are usually white, sometimes light blue or greenish white. The spur commonly points upward, being parallel with the main stem. The petals are covered with long, soft hairs.

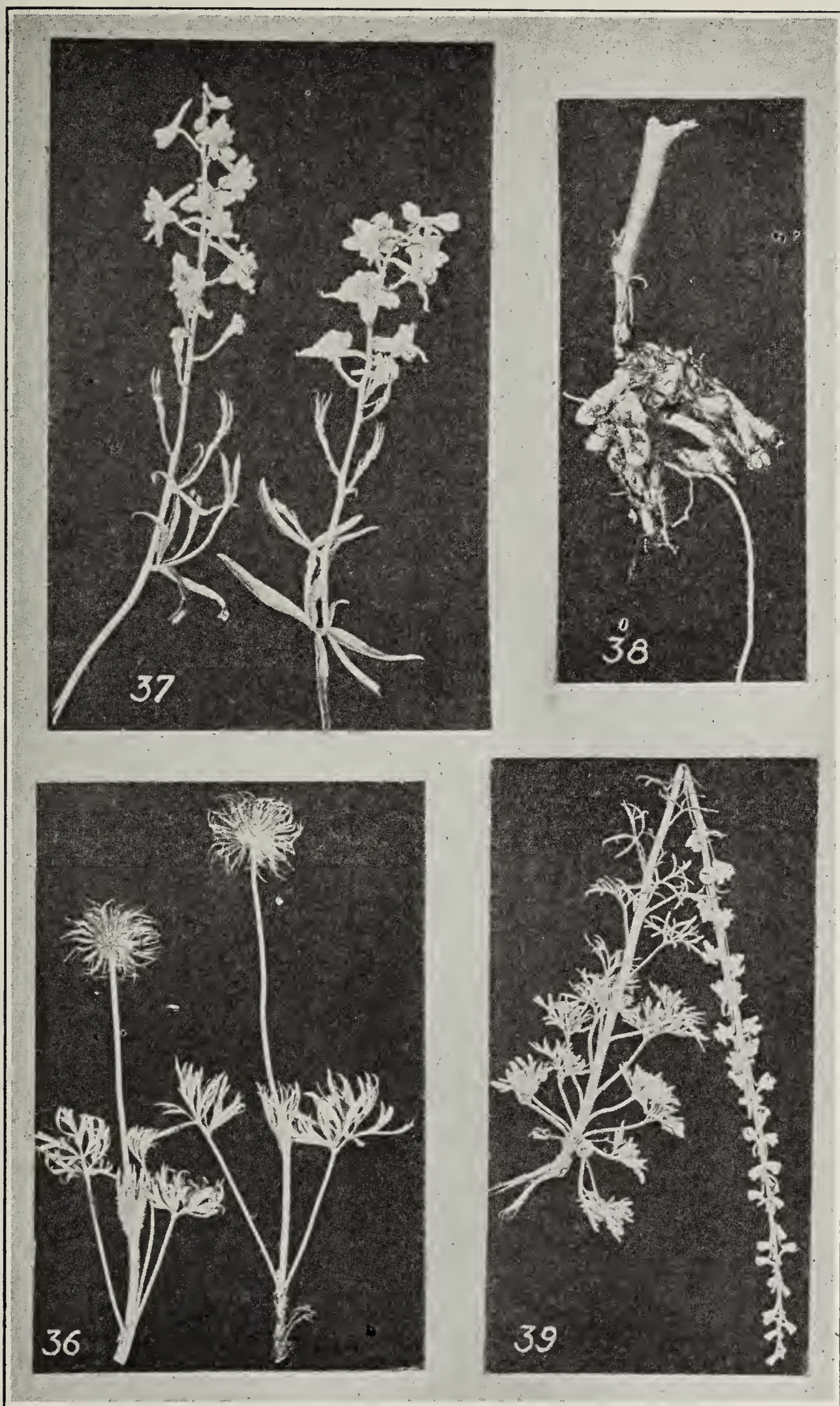
Subalpine Larkspur (*Delphinium subalpinum*).—This larkspur has a large woody root, and frequently grows to a height of 4 or 5 feet, although it may be much smaller. The leaves are not as finely divided as those of the three preceding species; they are divided into about 5 main divisions, each of which is further divided. The inflorescence also differs from the preceding, being dense and short, rather than loose and lengthened. The flowers are very deep blue. The fruit is short and smooth.

This is a plant of high altitudes, frequent at 10,000 to 11,000 feet, but often found as low as 8,000 feet, and above timber line. It is found in moist, rather shady situations and forms characteristic large dense beds.

Tall Larkspur (*Delphinium glaucescens*).—In this, several stems arise from a thick, woody root. The plant stands 1 to 5 feet high.



Figs. 27 - 35.—27, leaf of Nelson's larkspur; 28, leaf of Geyer's larkspur; 29, leaf of aconite; 30, leaf of wild geranium; note the two leaf-like structures (stipules) at the base of leaf stalk; 31, leaf of false mallow; 32, portion of leaf of false mallow, enlarged, showing the star-shaped hairs of the surface; 33, leaf of wind flower; 34, leaf of anemone (*Pulsatilla*); 35, leaf of Virgin's Bower.



Figs. 36 - 39.—36, anemone (*Pulsatilla*), the leaves of which are frequently mistaken for those of larkspur; 37, leaves and flowers of Nelson's larkspur; 38, easily detachable cluster of thickened, tuberous roots of Nelson's larkspur; 39, Penhard's larkspur.

The large leaves, 2 to 6 inches in diameter, are divided into 5 to 8 wedge shaped main divisions, each of which is further divided, usually into 3 segments. The pale blue flowers are in a rather short, loose cluster. The fruit is hairy. The tall larkspur is found mainly in the mountains, from 7,000 to 9,000 feet, in moist places.

Poisoning by larkspur.—There can be no question that in the mountainous districts of Colorado the several species of larkspur cause a greater loss to stockmen through poisoning than all other poison weeds combined. Laboratory experiments indicate that the different species vary as to their poisonous qualities, and that the poisonous qualities of any one of them is not to be depended upon at all times throughout the season. The white larkspur which grows on the plains east of the mountains, has never been reported to the Experiment Station, as having caused any trouble. Stavesacre which is derived from one species of larkspur has long been used in medicine. The eclectic physicians use it for its specific action on the reproductive organs but its principal use has been to destroy lice on the heads of children.



Fig. 40.—Geyer's larkspur (*Delphinium geyeri*).

Symptoms.—The symptoms manifested in affected animals are similar to those of aconite poisoning. Cattle are most often poisoned and the first thing noticed is stiffness, especially of the fore legs, and pronounced straddling of the hind legs in walking. The animal usually falls to the ground several times and the muscular movements become more and more irregular. There is drooling of saliva with frequent swallowing. Perhaps the most characteristic symptom is the quivering of the muscles, especially on the sides and legs. In fatal cases the animal dies in convulsions. There is not sufficient difference in the symptoms of poisoning by the different species of larkspur to warrant special consideration of each.

It is a well known fact that animals are most often poisoned from eating larkspur when it is wet, after a rain or snow storm, or in the early morning after a heavy dew or frost.

Since larkspur and death camas are both found on the same range at a time when they are most poisonous, it may be difficult to tell in a given instance which is responsible. The symptoms are quite characteristic in each instance and a comparison of the symptoms given should enable the reader to decide with a considerable degree of certainty.

Animals when poisoned, and if not restrained, will start for the nearest water hole; the death of many animals near water holes has been deemed sufficient cause in many instances for suspecting that the water has been maliciously tampered with by an enemy.

Areas that are badly infested with larkspur should be abandoned until the danger period has passed, which period will vary, according to altitude, from the middle of June to the first of August. When limited areas are particularly infested with larkspur, the practicability of fencing and of digging the plants is to be considered.

Treatment.—When an animal goes down from larkspur poisoning it should be turned until the head is higher than the body, to relieve the breathing. Under no circumstance should attempt be made to drive the animal further. The benefit derived by bleeding the animal, as claimed by some stockmen is questionable. When there is excessive bloating the rumer (paunch) should be punctured on the left side with a sharp knife (withdrawing it immediately after the puncture is made), or what is far better, with a trocar and cannula. This latter instrument, which costs but a dollar or two, should be kept at the ranch and carried by the range rider during the larkspur season. Potassium permanganate, as a chemical antidote, is found to be very effective in larkspur poisoning (discussed in connection with remedies for death camas), but the inconvenience of carrying quart bottles of the solution ready for use, renders it of little practical value.

Dr. C. Dwight Marsh has reported very satisfactory results from use of the following formula, administered hypodermically: See page 48 of copy for formula.

Physostigmin salicylate	1 grain
Pilocarpin hydrochlorid.....	2 grains
Strychnine sulphate.....	½ grain

Most stockmen are familiar with the use of a hypodermic syringe, having used it in vaccinating cattle for blackleg. A 4-dram, all metal syringe will be the most convenient, and can be secured at any instrument house. The drugs can be secured at drug stores in tablet form, and after being dissolved in water, are ready for immediate use. The amount of each drug indicated in the formula is intended to be given at one dose for an animal weighing 500 or 600 pounds. One-half ounce of boiled water should be used to dissolve the tablets and two or three doses can be carried along with the syringe, for immediate use. Dr. Marsh expresses his confidence in the above treatment in the following words: "If they (stockmen) are willing to try this remedy, they can without doubt save the lives of most of the animals poisoned during drives or round-ups."

MONKSHOOD, ACONITE (*Aconitum*)

The common monkshood or aconite (*Aconitum columbianum*) (figs. 39 and 41) in Colorado is a tall species, 3 to 6 feet high. The



Fig. 41.—Aconite (*Aconitum columbianum*)

plant is more or less hairy and sticky. The large leaves are cut into a number of segments. The flowers have the characteristic "hood"; this feature has suggested the name "monkshood." The flowers vary from blue to white. The fruit (fig. 26) is similar to that of larkspur. The species is prevalent in our mountains between the altitudes of 7,000 and 10,000 feet. Its preferred habitat is moist meadows and open woods. At 9,000 to 10,000 feet it is usually found growing among low shrubbery.

Poisoning by aconite.—There is some confusion in differentiating aconite from its near relative larkspur. In one locality on the "western slope" the tall larkspur has for years been called aconite. Aconite is a very poisonous plant but because of its limited distribution, and its widely scattered habit of growth, it is not much eaten. Animals have been seen to reject the plant even after taking it in the mouth, because of its peculiar local effect. The general effect of aconite is much the same as larkspur. There is great muscular weakness, shallow, irregular and labored breathing, a small and weak pulse, bloating, belching, drooling frothy saliva, and often a peculiar clicking sound caused from the constant attempt at swallowing. The pupils of the eye may be either contracted or dilated, but as the end approaches, remain dilated.

Treatment.—This consists essentially in overcoming the depression of the heart. Inhalations of ammonia, camphor, sulphuric ether, and hypodermic injections of digitalin or atropine. The formula recommended for hypodermic use in case of larkspur poisoning is quite appropriate in this case.

WILD CHERRY (*Prunus*)

The three common species of cherry in Colorado are the chokecherry (*Prunus melanocarpa*), wild red cherry (*Prunus pennsylvanica*), and sand cherry (*Prunus besseyi*).

Chokecherry (*Prunus melanocarpa*) (fig. 42). This is a tall shrub or small tree, sometimes attaining a height of 15 to 20 feet. The leaves are rounded or slightly heart-shaped at the base and pointed at the tip; the margin is marked by fine teeth. The flowers, of the true cherry type, are in long, unbranched clusters (see fig. 42), and in this respect chokecherry is distinguished from the wild red cherry and sand cherry; the two latter have the flowers in short clusters in the leaf axils. The ripe fruit of the chokecherry is black and has an astringent taste.

Chokecherry is found on plains and foothills throughout Colorado. It is quite a characteristic gulch plant.

Wild Red Cherry (*Prunus pennsylvanica*) (fig. 43). This is a small tree, in our region, seldom reaching a height of over 30 feet, usually much smaller, and even in some instances almost shrub-like. The leaves are 3 to 4 inches long and $\frac{1}{2}$ to 1 inch wide, rounded at the base and pointed at the tip; the margin is finely toothed. The flowers occur in the leaf axils, 4 or 5 in a group, all the flower-stalks

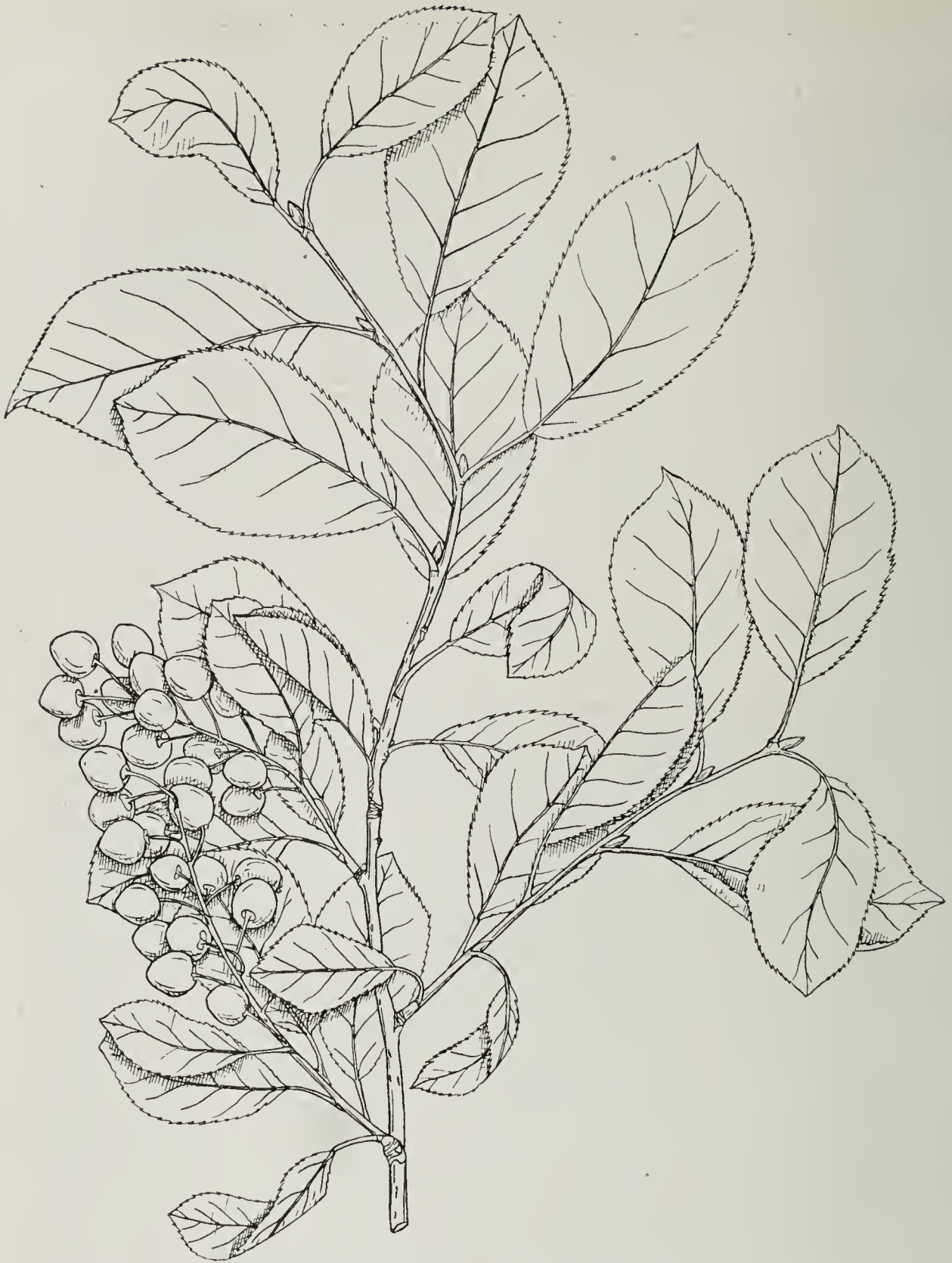


Fig. 42.—Chokecherry (*Prunus melanocarpa*)



Figs. 43 - 44.—43, wild red cherry (*Prunus pennsylvanica*); 44, Bessey's sand cherry (*Prunus besseyi*).

arising approximately from the same region on the stem. The small, spherical fruit has a light red color.

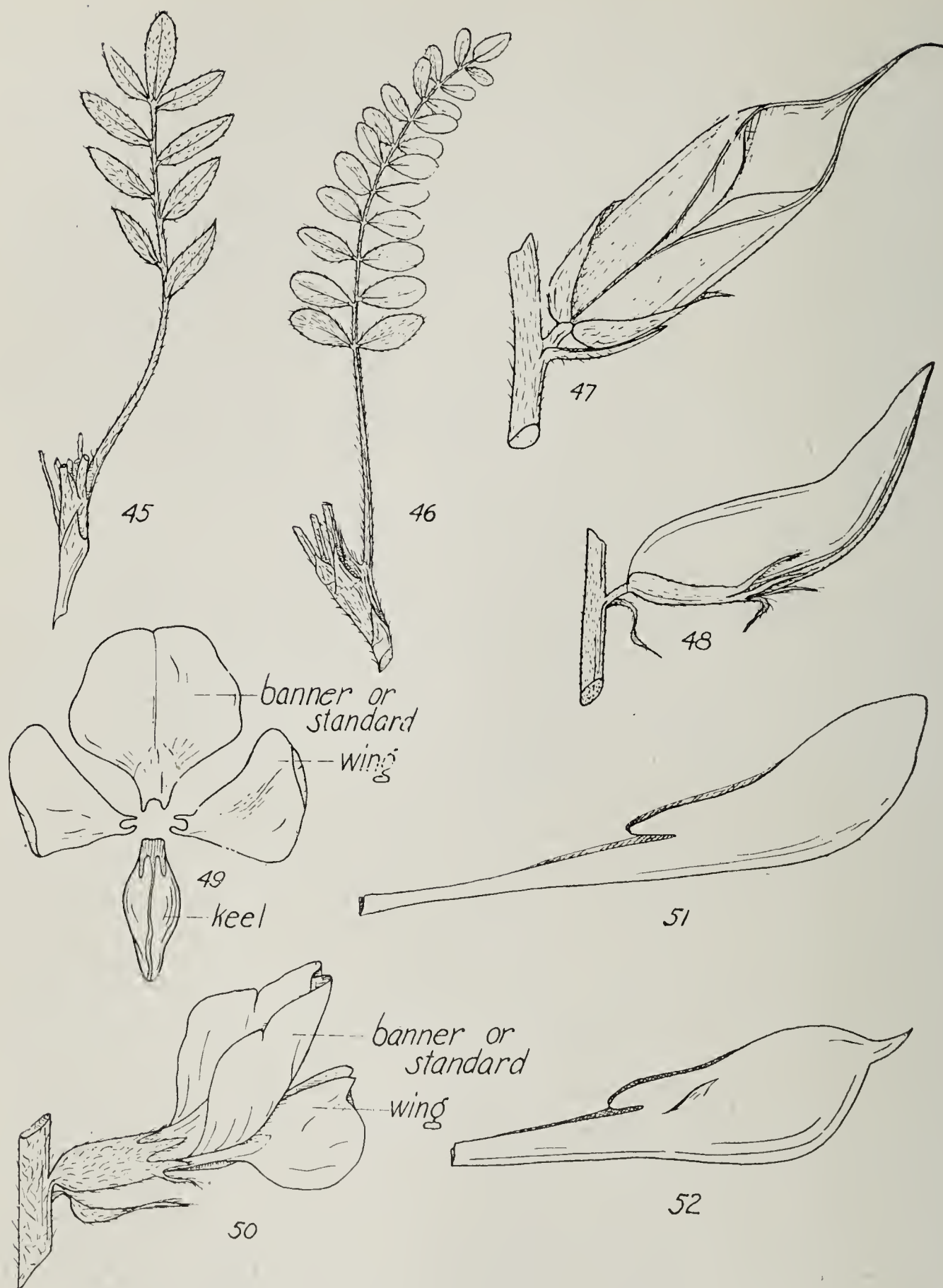
In Colorado, wild red cherry occurs along streams and on hillsides. It seems to be found only in the eastern half of the state, on plains and in the foothills.

Sand Cherry (*Prunus besseyi*) (fig. 44). The sand cherry is a low, often prostrate shrub, frequently but a few feet high. The leaves are thick, elliptic and toothed along the margin. The fruit is quite large, reddish-yellow in color. The sand cherry belongs to the plains of eastern Colorado, growing in dry, sandy and stony localities.

Poisoning by wild cherry.—The partially wilted branches of wild cherry are poisonous for cattle. The poison is prussic or hydrocyanic acid. The eating of the plant at the particular time when conditions are right for poisoning is not common. The symptoms and treatment for poisoning by foods that develop prussic acid will be found in connection with the discussion of sorghums.

PEA FAMILY (*Legumes*)

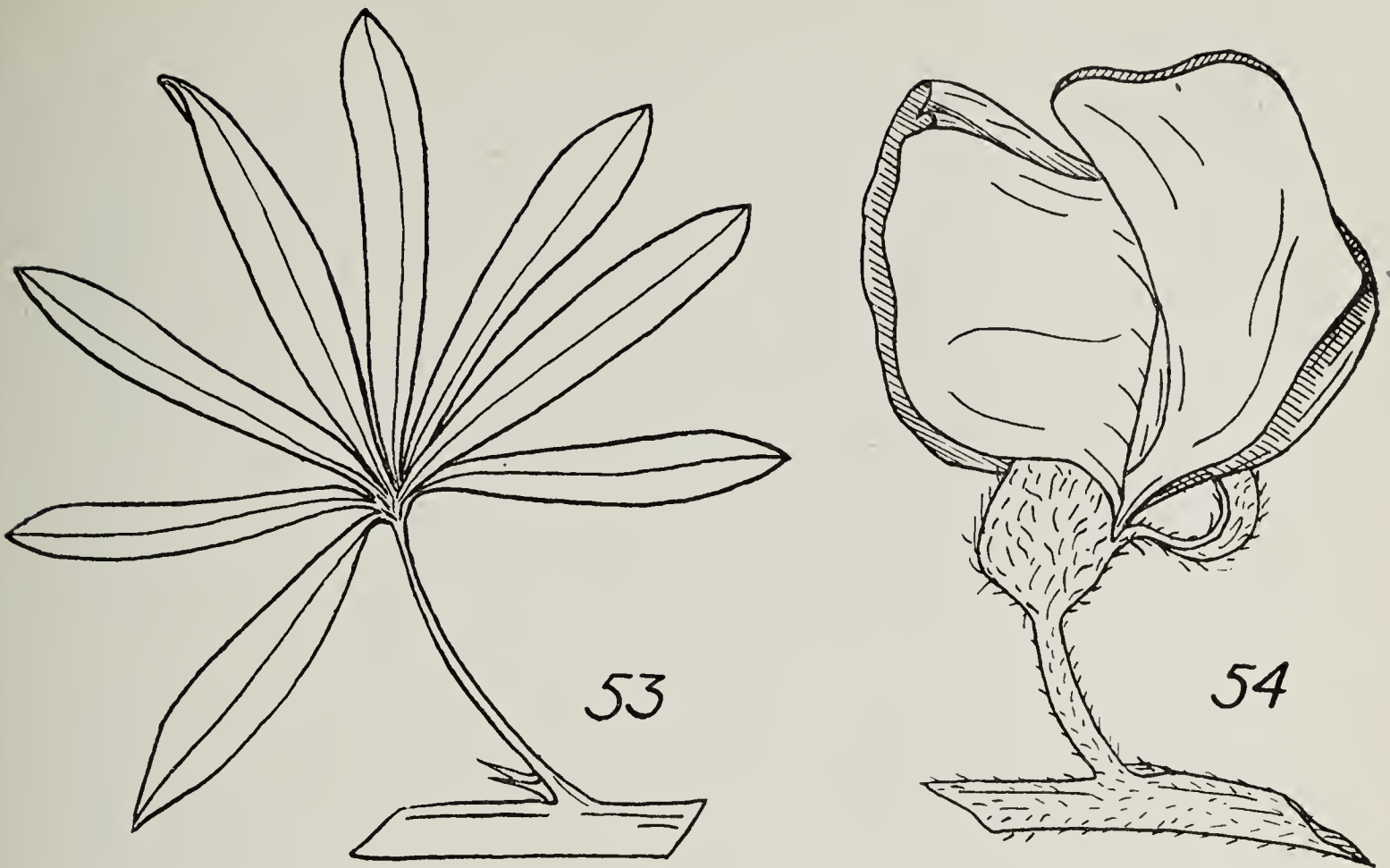
Before taking up a discussion of lupine and the locos, it will be well to give some general characteristics of the family of plants to which they belong. All members of the pea family are popularly known as "legumes." To this group belong such well-known plants as peas, beans, alfalfa, vetch, clover, cow-pea, sweet clovers, peanut, wild liquorice, buck bean, lupine and locos. Probably no family of plants is of greater agricultural importance, except it is the grass family. In addition to the important forage and human food value of members of the pea family, they have an important relation to soil fertility. Bacterial nodules are formed on the roots, and through the action of these and other soil bacteria, the soil is enriched in nitrates. For this reason, legumes are regularly employed as rotation crops with cereals and root crops. The flower of all legumes is characteristic. The accompanying figures are intended to make its structure clear. An examination of the flower of the alfalfa, pea or loco will, with the aid of figures 49 and 50, help one to get the pea type of flower fixed in mind. There are 5 greenish structures (sepals), at the base of the flower. They partially enclose the colored parts (corolla) of the flower. There are four main parts to the corolla of the flower: a broad upper one (*banner or standard*), two *wings*, one on each side, and a lower structure shaped like the keel of a boat, and called the "*keel*." The keel is really composed of two petals which are united along the middle line of the keel. It encloses the stamens, which produce the pollen, and also the ovary, which develops into the pod. The fruit of all peas is a pod or "legume." It consists of two halves which split apart (fig. 47) at maturity along their edges. There may be one or more seeds in a pod. For example, in the twisted pod of alfalfa there may be but one seed, while in the bean or pea there are several seeds. The leaves of all members of the pea family are divided into a number of divisions; that is, they are compound. And, at the base of the leaf-stalk, where it joins the stem, are almost always two small leaf-like structures, the *stipules* (fig. 46).



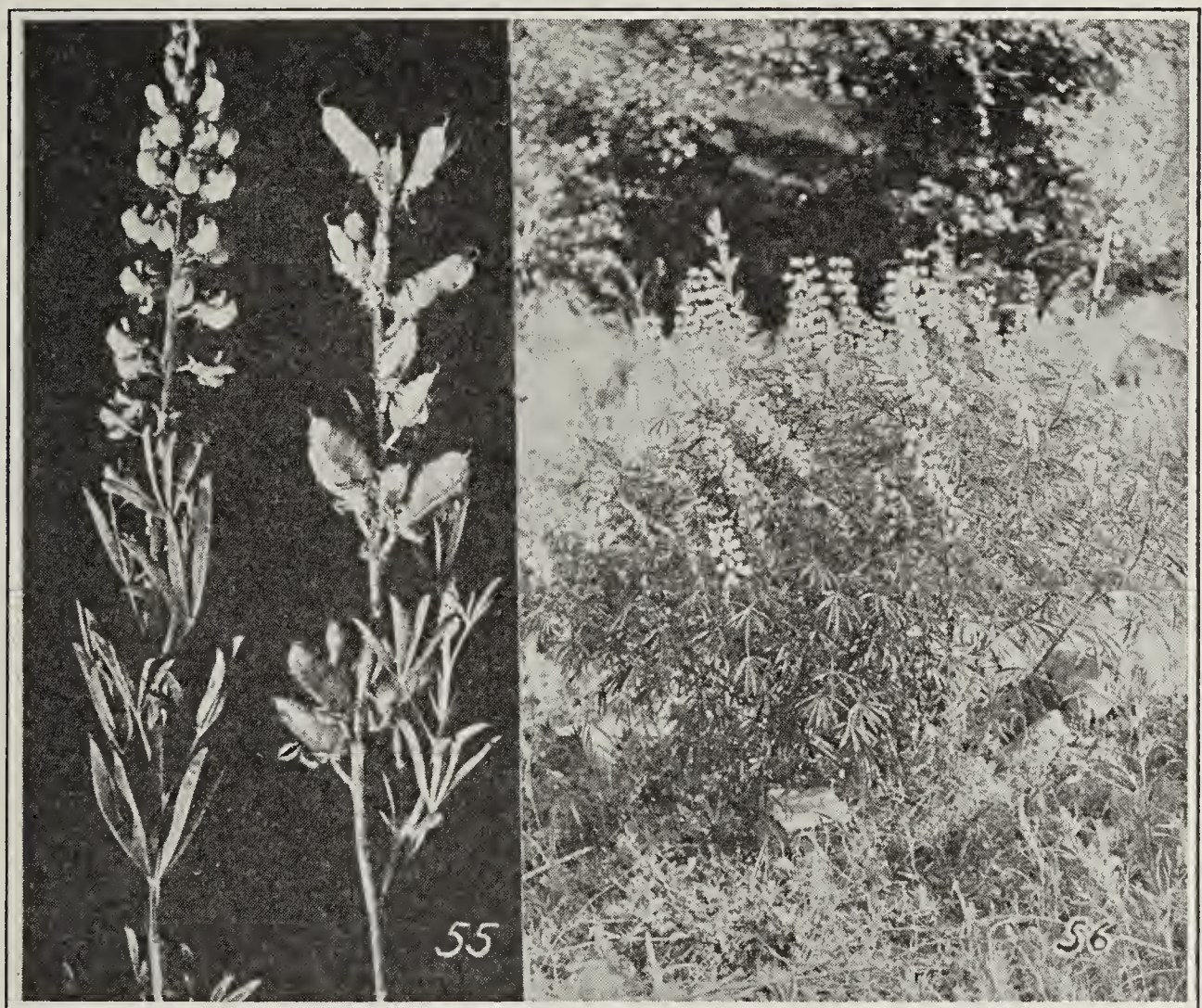
Figs. 45 - 52.—45, leaf of purple loco; 46, leaf of woolly loco; 47, pod of purple loco; 48, pod of woolly loco; 49, diagram of pea flower, dissected; 50, side view of purple loco flower; 51, keel of woolly loco; note the blunt point; 52, keel of purple loco; note the sharp point.

LUPINE, WILD BEAN, BLUE BEAN (*Lupinus*)

Lupines are herbaceous plants. They have leaves with the divisions all radiating from the end of the leaf-stalk (fig. 53). The flowers (fig. 54) are usually blue, and almost as broad as long. The pods are straight and usually much flattened. According to Rydberg's "Flora of Colorado," Bulletin 100, Colorado Agricultural Ex-



Figs. 53 - 54.—Spreading lupine (*Lupinus decumbens*). 53, single leaf; 54, flower.



Figs. 55 -56.—Spreading lupine (*Lupinus decumbens*): 55, flowers and fruit; 56, single plant; it is about 2 feet tall.

periment Station, there are 24 different kinds of lupine in Colorado, 6 or 8 of which are quite common. The others are recorded from but one or a very few localities.

The most common, at least conspicuous, lupines are tall, highly branching forms. A number of them form clumps, 1 to 2 feet tall. Very frequently a small annual lupine (*Lupinus pusillus*) is sent in by stockmen, being regarded with apprehension by them. This lupine is usually 4 or 5 inches high, much branched, and covered with long, stiff hairs. Another very common species is the spreading lupine (*Lupinus decumbens*) (figs. 55 and 56). Each plant forms a dense clump, 1 to 3 feet high. The leaflets are green above and silvery-hairy beneath. The flowers are in very dense clusters, and vary from blue to white. This species is abundant in rather deep soil at lower altitudes. It is also found throughout the foothills.

Poisoning by lupines.—Because of their practical importance, stockmen should become sufficiently acquainted with these plants to be able to recognize them at a glance. The white loco weeds are sometimes improperly called lupines. Lupines remain green and offer a succulent forage after most other plants have become dry. They are eaten mostly in the late fall and constitute one of the chief forage plants. Lupine is cut for hay in Montana and is eaten greedily by all kinds of stock. The principal poison in lupine is lupinotoxin and it is confined mostly to the seeds and seed pods. The chronic condition of lupine poisoning is known as lupinosis. It is apparent that lupine hay, to be safe, must be cut either before the pods have formed or late in the season after the pods have matured and most of the seeds fallen out. While most poisoning occurs from feeding the hay containing the seeds, there are cases reported in which animals have been poisoned from grazing on lupines in the late summer and fall.

Symptoms of poisoning.—Chronic lupine poisoning is not common in this country, although a few cases have been noted. In acute cases there is cerebral congestion accompanied from the start by great mental excitement. Sheep are more often poisoned than horses or cattle. Sheep at first become frenzied, butt into things, fall over each other, show irregularity of movements, and finally have violent spasms, and in fatal cases die in convulsions. The symptoms somewhat resemble those of poisoning by strychnine.

Preventive and remedial measures.—Prevention consists in avoiding the ripe lupines both on the range and in the hay. Acute cases of lupine poisoning are not common in Colorado and no experiments have been made in treating the disease. Potassium permanganate would probably be effective as a chemical antidote if given early in the attack before too much poison is absorbed from the stomach. After absorption the physiological effects may be counteracted by morphine, chloral and other sedatives.

LOCO WEED

The name "loco weed" is applied to a great many different plants. The true locos and those which are commonly mistaken for locos all belong to the pea family. All are herbs. They have the typical pea flower: 5 green sepals, a white, purple, or red corolla composed of a single large banner, two wings and a keel. The loco fruit is a pod ("legume"). The leaves are compound, that is, made up of a number of separate leaflets. There is always an odd number of leaflets (fig. 45), which means that a leaflet, not a tendril, is at the tip of the leaf. In nearly all cases the leaflets are numerous, and come off on either side of the main axis of the leaf, seldom radiating from the end of the main axis, as in lupine.

The true locos and those resembling loco belong to two groups (genera) of the pea family. These groups are known by botanists as *Aragallus* and *Astragalus*. The common purple loco is an *Aragallus*, while the woolly loco is an *Astragalus*. Of course there are many different species of *Aragallus*, and also many of *Astragalus*. But the two large groups, with all their species, are distinguished from each other quite easily by an examination of the flower. If the two wings of an *Aragallus*, for example the purple loco (*Aragallus lambertii*) flower, are pulled aside so that one may see the tip of the keel, it will be seen that this tip is sharp-pointed (fig. 52). On the other hand, the keel of the *Astragalus* flower, for example woolly loco, (*Astragalus mollissimus*) is blunt and rounded at the tip (fig. 51). There are recorded 9 different sorts of *Aragallus* in Rydberg's "Flora of Colorado," and in the same book 81 different species that might be referred to the genus *Astragalus*.

As was intimated above, there are many different plants that are called loco weed. This name is most commonly applied, however, to two species; these are the purple or stemless loco (*Aragallus lambertii*) and the woolly loco (*Astragalus mollissimus*). It is positively known that these two plants cause the loco disease. It is quite probable, however, that a few, at least, of the many allied forms, also possess poisonous properties. Many species, besides the purple loco and woolly loco, have been sent into the Experiment Station, with the statement that they were the cause of locoin. Many of these species held in suspicion, resemble either the purple loco or the woolly loco. It is well for the stockman to thoroughly familiarize himself with the two known poisonous species, namely, the purple or stemless loco and the woolly loco.

Purple or Stemless Loco (*Aragallus lambertii*) (fig. 57). The purple loco is perennial. It is apparently stemless. The numerous leaves and flowering stems arise from a hard, woody crown. The plant has a tufted appearance. Where the leaves join the crown, there are a number of papery scales (stipules). The plants are usually 8 to 14 inches high. Each leaf (fig. 45) has a number of oblong to narrow leaflets, from $\frac{1}{2}$ to $1\frac{1}{4}$ inches long. They are covered with



Fig. 57.—Purple loco (*Aragallus lambertii*).

silky hairs that lie closely against the leaf surface; often the leaves are smooth. The flowers (fig. 50) are scattered along the end of a leafless stem. This stem may be silky hairy or smooth. The flowers are longer than broad. They are usually purple, but sometimes violet or white. The pod (fig. 47) is oblong, hairy, rather leathery and measures about $\frac{1}{2}$ to $\frac{3}{4}$ of an inch long.

Purple loco grows in dry open soil. It is not found in low, moist land, or to any extent in shaded situations. It is found throughout Colorado, from the lowest altitudes up to about 9,000 feet. In the mountains it is most prevalent in the open parks, where it occurs in dry grassland. At the lower altitudes it is in bloom in early June. At 9,000 feet it comes into flower the latter part of June and the first of July.

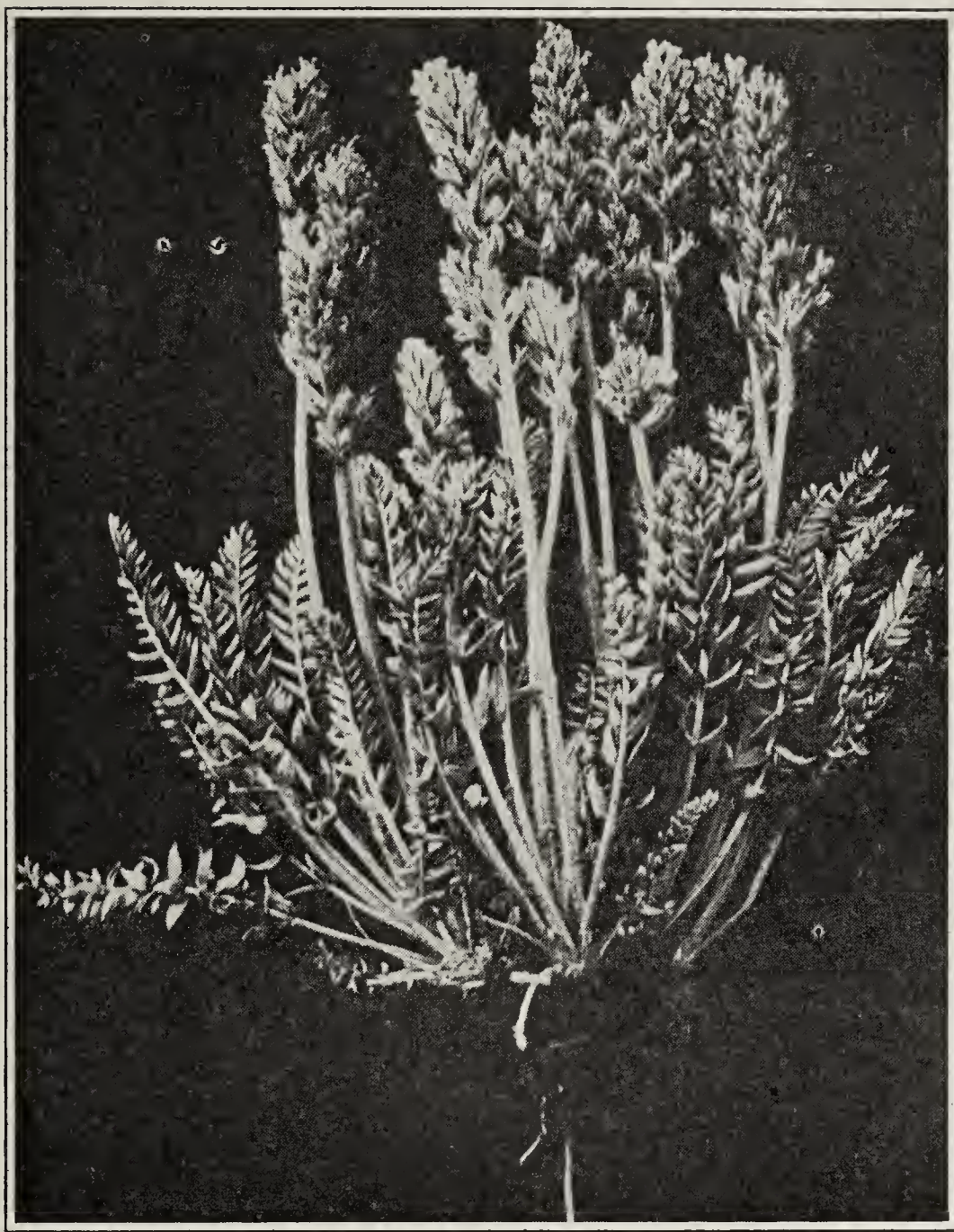


Fig. 58.—Richardson's loco (*Aragallus richardsonii*).

There is a variety of the purple loco (*Aragallus lambertii sericeus*) which is stouter in appearance and has more silky, and broader leaflets than the regular form.

White-Flowered Loco (*Aragallus albiflorus*).—This grows in about the same habitats as the purple loco. It precedes the purple one, however, by a week or so. It also extends to higher altitudes (up to 11,000 feet). It is a more robust plant. It is covered with silvery hairs. There are silky white hairs on the calyx and with them, interspersed, a few black hairs. The flower is white, with a characteristic purple tip on the keel. The plant is held with suspicion.

Richardson's Loco (*Aragallus richardsonii*) (fig. 58).—This is found only in the mountain valleys. It is readily distinguished from the preceding locos by the leaf; in it the leaflets are arranged

in bundles of 3 or 4 on the stem. The whole plant is more or less hairy; the corolla is large and blue. Suspected of being poisonous.

Woolly Loco (*Astragalus mollissimus*).—This is a perennial (fig. 59) with a short, stout stem from which arise numerous leaves,



Fig. 59.—Woolly loco (*Astragalus mollissimus*).

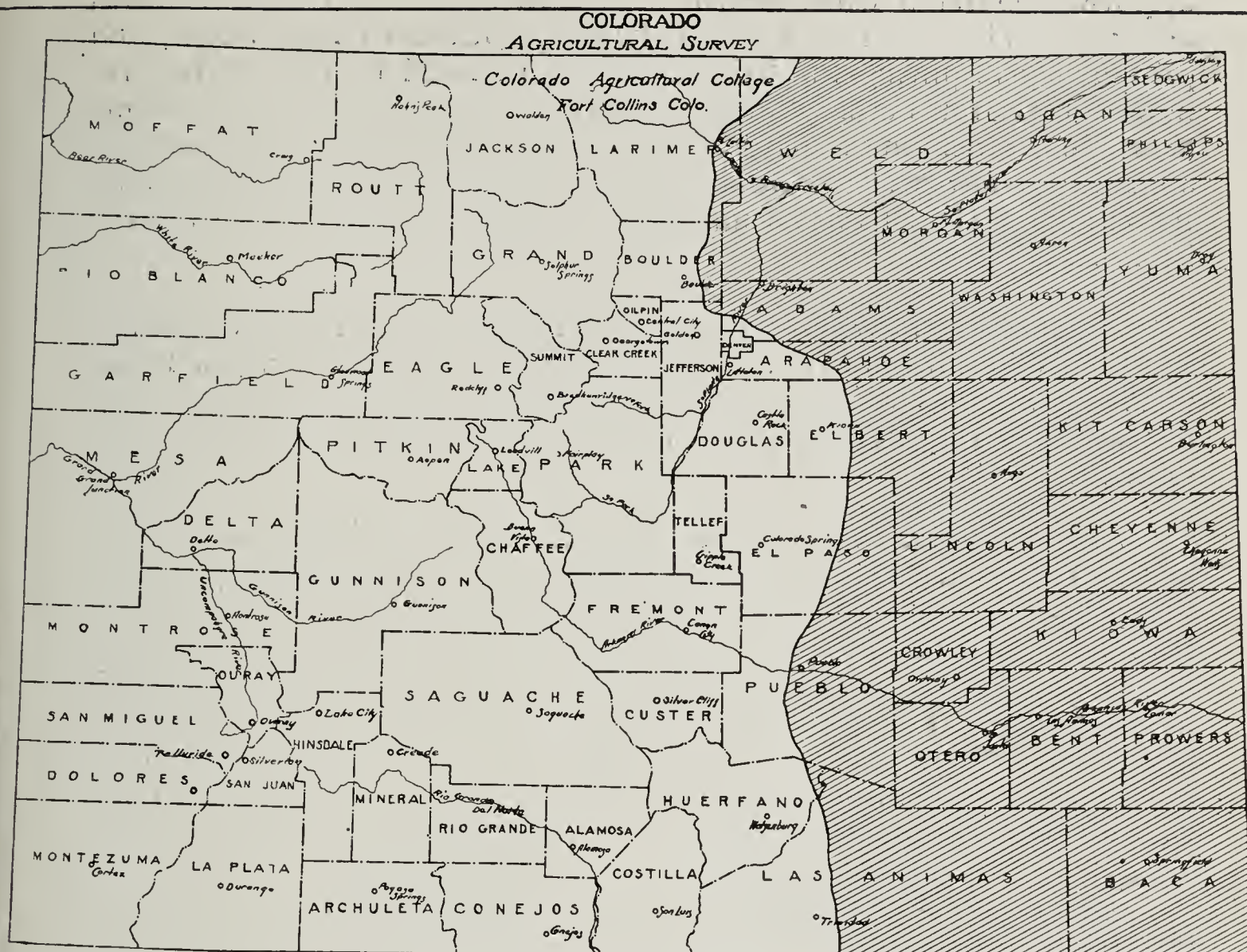


Fig. 61.—The shaded portion shows the geographical range of woolly loco in Colorado.

and stems bearing flowers. The entire plant is very densely hairy, the hairs being long, silky and somewhat matted together. There are numerous leaflets, which usually measure from one-half to five-eighths of an inch long. The violet colored flowers are crowded; they are longer than broad. The mature pod is smooth, leathery, curved, and from one-half to three-fourths of an inch long.

The woolly loco prefers dry soil. It is found only at lower altitudes in the eastern half of Colorado. It is a Great Plains plant (fig. 61). It blooms in late May and early June.

Symptoms resulting from eating locos.—The symptoms are so well known to stockmen that a lengthy discussion of them at this time would be superfluous. The condition may be summarized as a cerebral disturbance with impairment of the special senses and incoordination of muscular movements. Horses, cattle and sheep are affected. The claim is made in Montana that cattle are the least susceptible. The loco weed habit is acquired by imitation and encouraged by scarcity of forage grasses. Stock are not liable to eat poisonous plants when good food is available. If stock can be kept from

acquiring the habit when food is scarce, there will be very few locoed animals. When first seen eating large quantities of loco weeds, and presumably acquiring the habit, an animal should be immediately removed from the herd. Young animals are more apt to acquire the habit than older ones. The habit assumes the form of an insatiable appetite for loco weeds, and as a result from eating these exclusively, the animal suffers from an unbalanced ration and from lack of nourishment.

Poisonous principle.—The nature of the poison in loco weeds has not been determined. It was thought at one time that barium found in the plants was responsible, since the symptoms in barium poisoning in some respects simulated those of locoism, but this was later disproven.

Preventive measures and treatment.—The most important measure is to remove the affected animals from loco infested pastures. Many letters are received at the Experiment Station asking for a cure for locoed animals and in most instances the animals were known to still have access to the weeds. A "cure" in a case like this is impossible. The afflicted animal should first be taken from the infested area, and given a physic (raw linseed oil), and fed well on hay and grain of the best quality. Fowler's solution of arsenic mixed with the grain may be given as an alterative and tonic twice a day.

The dose for horses and cattle is one-half ounce, and for sheep one teaspoonful. This treatment should not be given continuously longer than two weeks. If the animal can be placed under the care of a competent veterinarian, strychnine and other remedial measures may be tried. If not too badly diseased, cattle and sheep, with good care and proper treatment, will recover sufficiently to fatten for the block. Horses will recover sufficiently, in most cases, to render a more or less valuable service, but with few exception they do not become normal and dependable.

BUCKBEAN (*Thermopsis*)

The common buckbean or yellow wild pea in the state is one with widely-spreading pods (*Thermopsis divaricarpa*). It is a tall perennial with large leaves divided into 3 leaflets that arise at and radiate from the end of the leaf-stalk. At the base of the leaf-stalk, there are two large leaf-like structures, the stipules. The flowers are large, pea-like, and yellow. The pods are 3 to 4 inches long, 1-4 inch wide, and spread out from the stem. The plant blooms in the early spring, forming large, bright yellow patches. It grows in rather deep soil along streams, and in draws. It is distributed throughout the state from 5,000 to 11,000 feet altitude.

The buckbean is regarded with suspicion by some. No authentic cases of poisoning from it have come to our attention.

SNOW-ON-THE-MOUNTAIN (*Euphorbia marginata*)

This bright green, erect annual (fig. 62), 2 to 4 feet high, is conspicuous, due to its white-margined upper leaves; hence the name "snow-on-the-mountain." The plant has a milky juice. It grows on the plains and lower foothills, and is most conspicuous in August.

Poisoning by snow-on-the-mountain.—More than one hundred species of spurge grow in the United States and many of them are indigenous to Colorado. They have a milky juice that is acrid and corrodes the skin and mucuous membranes whenever applied. The milky juice has been used imperically to remove warts and freckles. The snow-on-the-mountain is a very common plant, but is rarely if ever eaten by animals. The plant has not been sufficiently investigated to warrant any definite conclusion regarding its poisonous character. On some closely cropped ranges, this plant will be found as one of a few that has not been molested. Near Lamar, Colorado, where many sheep had died, presumably from eating poison weeds, this particular plant was found to have been denuded of foliage by grasshoppers but without any apparent diminution of their numbers. There was no evidence that sheep had eaten the plants.



Fig. 62.—Snow-on-the-mountain (*Euphorbia marginata*). The upper leaves have white margins.

SUMAC (*Rhus cismontana*).

The sumac (fig. 63.) of Colorado is a shrub 3 to 7 feet high. The compound leaves have numerous finely-toothed, smooth leaflets that are whitish beneath. The inflorescence is dense and spherical. The fruit is one-seeded and covered with reddish hairs. The leaves turn bright red in the autumn. It is found throughout the state at lower elevations, usually forming thickets.

The red fruit of sumac is considered poisonous by some. No cases of poisoning, however, have been brought to our attention.



Fig. 63.—Sumac (*Rhus cismontana*)

WESTERN POISON IVY, POISON OAK (*Rhus rydbergii*)

Western poison ivy (fig. 64), or poison oak, is the only plant in the Rocky Mountain region that is poisonous to the touch. It is a low shrub, 1 to 2 feet high. Unlike the eastern poison ivy, it does not climb or creep. The leaflets come off in threes and when young are folded along the midrib, and quite frequently tinged with



Figs. 64 : 65.—64, poison ivy (*Rhus rydbergii*); 65, skunk-bush (*Rhus trilobata*).

purple or dark red. The small yellowish-green flowers occur in clusters in the axils of the leaves. The fruit is globular, berrylike, shining-white, and often persistent on the plant during the winter. It usually grows in rather moist, shaded situations or among rocks. Poison oak or poison ivy should not be confused with scrub oak.

Some people are very susceptible to ivy poisoning. In the human it causes intense inflammation of the skin, with vesicles, edema, itching, and spreads rapidly. A few reports have come to this office to the effect that animals have been poisoned from eating poison ivy, but these reports have not been verified. From a veterinary standpoint, it has little significance as a poisonous plant.

For poisoning by ivy, a popular and effective remedy consists in washing the inflamed skin with a solution made by adding powdered sugar of lead to alcohol, of 50% grade, until no more will easily dissolve.

SKUNK-BUSH (*Rhus trilobata*)

This is a much-branched shrub (fig. 65), 2 to 5 feet high. The leaves are usually 3-lobed. The flowers are in dense clusters, small,

yellowish, and make their appearance before the leaves. The fruit is spherical, red and covered with sticky hairs. The plant has an unpleasant odor, especially when bruised. It grows at lower elevations throughout Colorado, seldom going above 7,000 feet. It is not browsed by animals, because of its objectionable odor.

FALSE MALLOW (*Malvastrum coccineum*)

This is a low, silvery-hairy plant, 4 to 8 inches high. Leaf shape is shown in fig. 31. The flowers have a characteristic brick-red color. The plant grows in dry soil throughout the state, from 4,000 to 9,000 feet elevation. Reports of poisoning by this plant have not been authenticated. Presumably, it is not poisonous.

COWBANE, WATER HEMLOCK (*Cicuta occidentalis*)

This very poisonous plant is a stout perennial, 3 to 7 feet tall. The stem is hollow, smooth, and green. The plant has a very char-

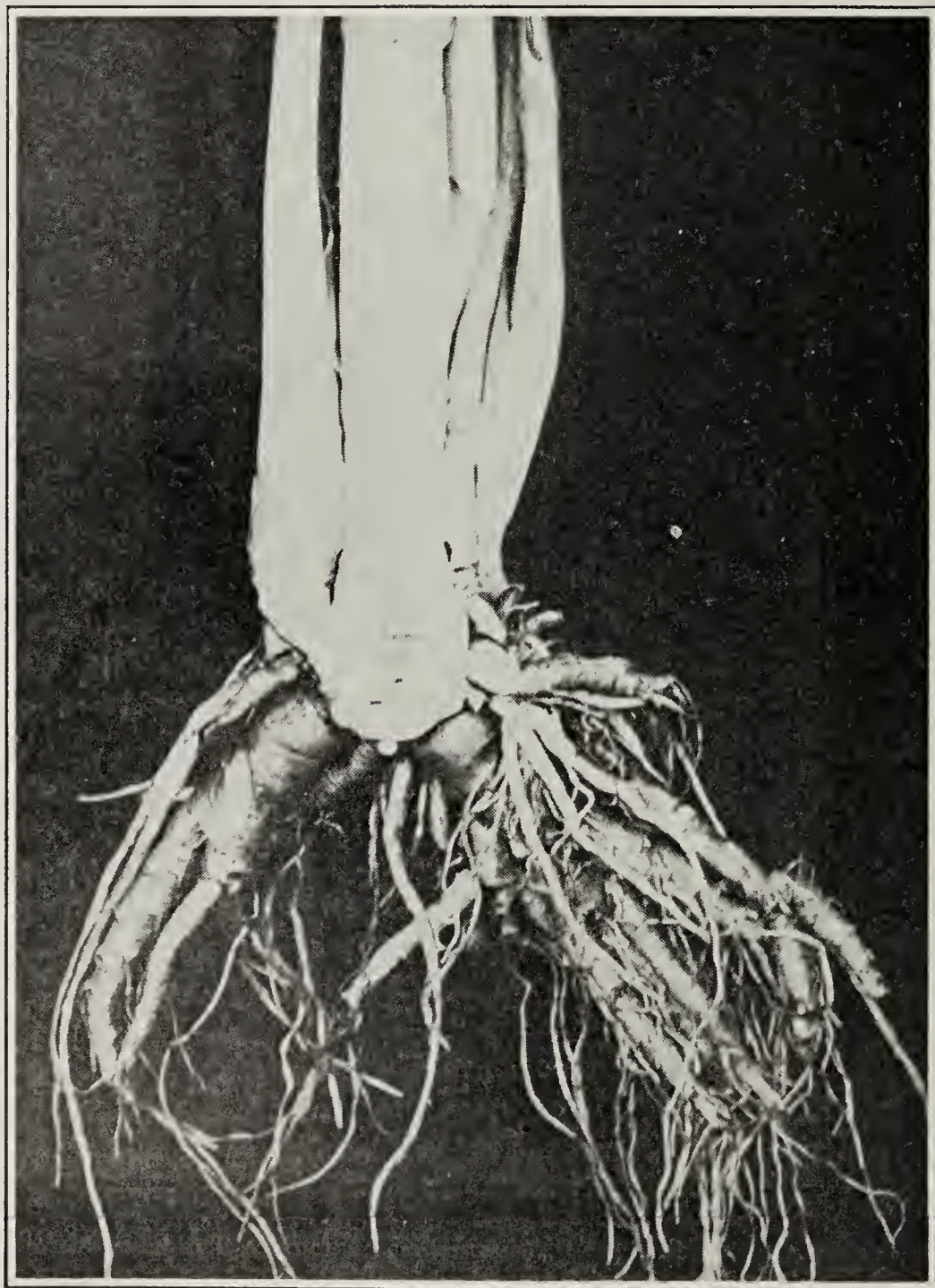


Fig. 66.—Roots of water hemlock (*Cicuta occidentalis*). Note that the spindle-shaped roots are clustered; also observe the cross-partitions.



Figs. 67 - 73.—67, root of common wild parsnip; note that there is a single root; 68, leaf of water hemlock; 69, cross section of stem of common wild parsnip; 70, cross section of stem of water hemlock; 71, end leaflet of leaf of common wild parsnip; 72, lateral leaflet of common wild parsnip; 73, leaf of water parsnip sometimes mistaken for water hemlock.

acteristic bunch of thick spindle-shaped roots which contain a yellow, gummy secretion. These are further characterized by being divided into chambers, internally, by cross-partitions. These features are brought out in fig. 66. Common garden parsnip (*Pastinaca sativa*) that has gone wild, and popularly known as "wild parsnip," is readily mistaken for the water hemlock. The wild parsnip, however, has a single thick, fleshy root (fig. 67), and not a cluster of roots as has the water hemlock. These two plants are also distinguished by their leaves (figs. 68, 71 and 72). The leaves of water hemlock are doubly divided, the leaflets being finely toothed along the margin. The stem of cowbane (fig. 70) is smooth, that of wild parsnip



Figs. 74-77.—74, common wild parsnip (*Pastinaca sativa*); 75, tall angelica (*Angelica ampla*); 76, cow parsnip (*Heracleum lanatum*); 77, swamp laurel (*Kalmia polifolia*).

(fig. 69) roughened. The small, white flowers are arranged in umbels as in common parsnip (fig. 74); the fruit resembles that of parsley.

Water hemlock is found throughout the Rocky Mountain section from 4,000 to 8,000 feet elevation. It grows in wet or swampy situations, on streams and ditch banks.

Water hemlock has been distinguished from ordinary garden parsnip in its wild state. It is also sometimes confused with the water parsnip (*Sium cicutaefolium*) (fig. 73). This plant belongs to the same family (parsnip or carrot family) as water hemlock, and is found growing in wet places, but it does not have a cluster of fleshy roots as does the water hemlock; furthermore the leaves are not doubly compounded (fig. 73). The water parsnip has been noted in but a few localities of the state. It is reported as poisonous, but it is likely that it has been confused with the water hemlock.

Poisoning by water hemlock.—The American water hemlock is one of the most poisonous plants native to the United States. Every year cases are reported of people, more often children, poisoned from eating the roots of water hemlock, mistaking it for wild garden parsnip. Most of these cases are fatal. The root of a single plant has been known to kill a horse in little less than an hour. Poisoning usually results from eating the roots, but there are instances in which fatal poisoning followed from eating the tops of young plants, and there is strong suspicion that the dried plants in hay may at times be eaten in sufficient quantity to cause poisoning. The roots become accessible by plowing, or as frequently happens, the earth is washed away from around the roots on ditch banks. The roots are eaten with more apparent relish than are the dried tops, by both cattle and horses.

Symptoms of poisoning.—The symptoms are quite characteristic and should be easily differentiated by the layman from those of camas, loco, larkspur or lupine poisoning. The first pronounced symptom is akin to acute spasmodic colic without intermissions from pain. Frequent attempts at micturition and defecation are accompanied by spasmodic contractions of the muscles of the abdomen. The animal is in great agony, and, when prostrate, beats its head violently upon the ground. There is "frothing at the mouth" and in cases that last for several hours, blood may appear in the feces and urine. The spasm rapidly become more and more severe as the brain excitement increases, and the animal finally become unconscious and dies in the most violent convulsions.

Treatment.—In very acute cases animals may die in fifteen minutes; in such, treatment is out of the question. If potassium permanganate (as recommended in connection with death camas) can be administered early, it probably will be effective. Melted lard and raw linseed oil are indicated. To relieve the pain, morphine

may be given in doses as follows: For sheep, $1\frac{1}{2}$ grains; for cattle and horses, 3 to 5 grains. For horses or cattle, 2 drams of chloroform or 1 ounce of chloral hydrate may be given, highly diluted, by the mouth. If the permanganate has already been given, other drugs should not be given by the mouth.

Cow parsnip (Heracleum lanatum) (fig. 76).—This is a stout plant, 4 to 8 feet tall, with large compound leaves that are divided into three main lobes. The base of the leaf-stalk is very much broadened. The flowers are white and in broad umbels. The fruit resembles that of common garden parsnip. It grows in wet ground, especially along streams, throughout the state from 5,000 to 10,000 feet altitude.

The cow parsnip may sometimes be confused with the tall angelica (*Angelica ampla*) (fig. 75). This is a plant from 5 to 8 feet tall, but is distinguished from the cow parsnip by its purplish stems, and leaves which are twice compound.

The cow parsnip is found in situations similar to those in which water hemlock grows. It can easily be distinguished from the water hemlock, however, by its much greater size, and coarser character. Because of its coarseness, it is not often eaten and is not presumed to be poisonous.

AMERICAN OR SWAMP LAUREL (*Kalmia polifolia*)

The forms of the American or swamp laurel (fig. 77) growing in the Colorado mountains are dwarfed as compared with the eastern ones. With us it is a low, smooth shrub, 8 to 20 inches tall. The leaves are evergreen, shiny-green above, paler beneath, the margin often rolled in. The flowers are $\frac{1}{2}$ inch broad and lilac-purple in color. The plant grows in mountain bogs, seldom below 10,000 feet elevation.

Poisoning by swamp laurel.—Colorado stockmen generally know very little of swamp laurel as a poisonous plant. This is probably accounted for from the fact that it grows only on the very high ranges, where relatively few animals graze. It is much dreaded in some sections, however.

SMALL DOGBANE (*Apocynum androsaemifolium*)

This plant (fig. 78) has a milky juice. It grows from 1 to 5 feet tall, and has widely spreading branches. The opposite leaves are tipped with a very short abrupt point. The flowers are pink.

The plant grows in shaded situations throughout our range, from an altitude of 7,000 to 9,500 feet.

Indian Hemp (Apocynum cannabinum).—Like the preceding, this plant (fig. 79) has a milky juice. The stems are 3 to 6 feet tall, and branching. The leaves are opposite and tipped with a short abrupt point. The flowers are greenish-white. It grows at lower altitudes throughout Colorado.

Poisoning by dogbane and Indian hemp.—Several representatives of the dogbane family contain active alkaloids which are used in



Figs. 78 - 79.—78, small dogbane (*Apocynum androsaemifolium*); 79, Indian hemp (*Apocynum cannabinum*).



Figs. 80 - 81.—80, showy milkweed (*Asclepias speciosum*); 81, low milkweed (*Asclepias pumila*).

medicine. Indian Hemp is perhaps the best known. It is used as an emetic, cathartic and diuretic. It contains the glucoside *apocynein* and a bitter extractive *apocynin*. Both dogbane and Indian hemp are looked upon with suspicion by stockmen, and they no doubt poison animals occasionally.

MILKWEED (*Asclepias*)

The milkweeds, as a group, are quite well-known. All of them are regarded with suspicion by stockmen, and in some cases at least, this suspicion is justified. All plants with a milky juice are not "milkweeds", that is, of the group known botanically as "*Asclepias*." For



Fig. 82.—Whorled milkweed (*Asclepias verticillata*).

example, prickly lettuce, sow thistle, and prickly poppy all have a milky juice, yet are not true milkweeds. The three above-mentioned have alternate leaves, while the true milkweeds have opposite leaves.

There are many species of true milkweeds within our borders. All are herbs, with opposite leaves (rarely alternate), or sometimes several at a joint on the stem. The leaves and stems are often somewhat woolly, sometimes smooth. The flowers are in umbels, pink, purplish, or white in color, and peculiar in shape. The fruit is a pod which splits open at maturity allowing numerous seeds to come out, each of which has a silky tuft of hairs at the end.

The most common milkweed in our section is the showy milkweed (*Asclepias speciosa*) (fig. 80). It is perennial 2 to 5 feet high with large, opposite leaves, and purplish flowers in spherical, terminal clusters. It grows in good, rather moist soil on plains and in foothills throughout the state.

The low milkweed (*Asclepias pumila*) (fig. 81) is 2 to 15 inches tall, and grows from a woody root. The leaves are very narrow and crowded on the stem. The pods are long, slender and much smaller than those in the preceding species. It prefers dry, sandy soil. It is most common at low altitudes.

The whorled milkweed (*Asclepias verticillata*) (fig. 82) is a leafy plant, 1 to 2½ feet high. The long, narrow leaves are several at a joint of the stem. It grows on dry plains.

There are several so-called green milkweeds in Colorado, the chief one being the green-flowered green milkweed (*Acerates viridiflora*). It is a plains plant.

Poisoning by milkweeds.—Many of these plants have an acrid juice. The showy milkweed is said to be poisonous. It contains *asclepien*. Another species (*A. verticillata*) grows extensively along river bottoms and native meadows of Colorado, and is suspected of being poisonous. At Olathe several cattle died with symptoms of poisoning that had eaten hay containing considerable quantities of this weed. A sack of the plants was sent to the Experiment Station for examination. Rabbits refused to eat it and watery and alcoholic extracts were tried, but the chances are that the animals in this instance died from some other cause. While many of the milkweeds are poisonous they are for the most part rejected by animals.

BLACK NIGHTSHADE, STUBBLE-BERRY (*Solanum nigrum*)

An annual low, spreading plant (fig. 83.) with oval leaves. The white flowers are in small drooping groups along the side of the stem. They are of the potato type: 5-parted calyx, 5-parted corolla, 5 stamens. The berries are black, smooth and spherical. The plant is introduced from Europe and assumes weed habits with us. It occurs at low altitudes in the states, it is not abundant, however.

THREE-FLOWERED NIGHTSHADE, WILD TOMATO (*Solanum triflorum*)

A low, spreading annual (fig. 84) with deeply cut leaves. The flowers are usually arranged in groups of three, on nodding stalks,

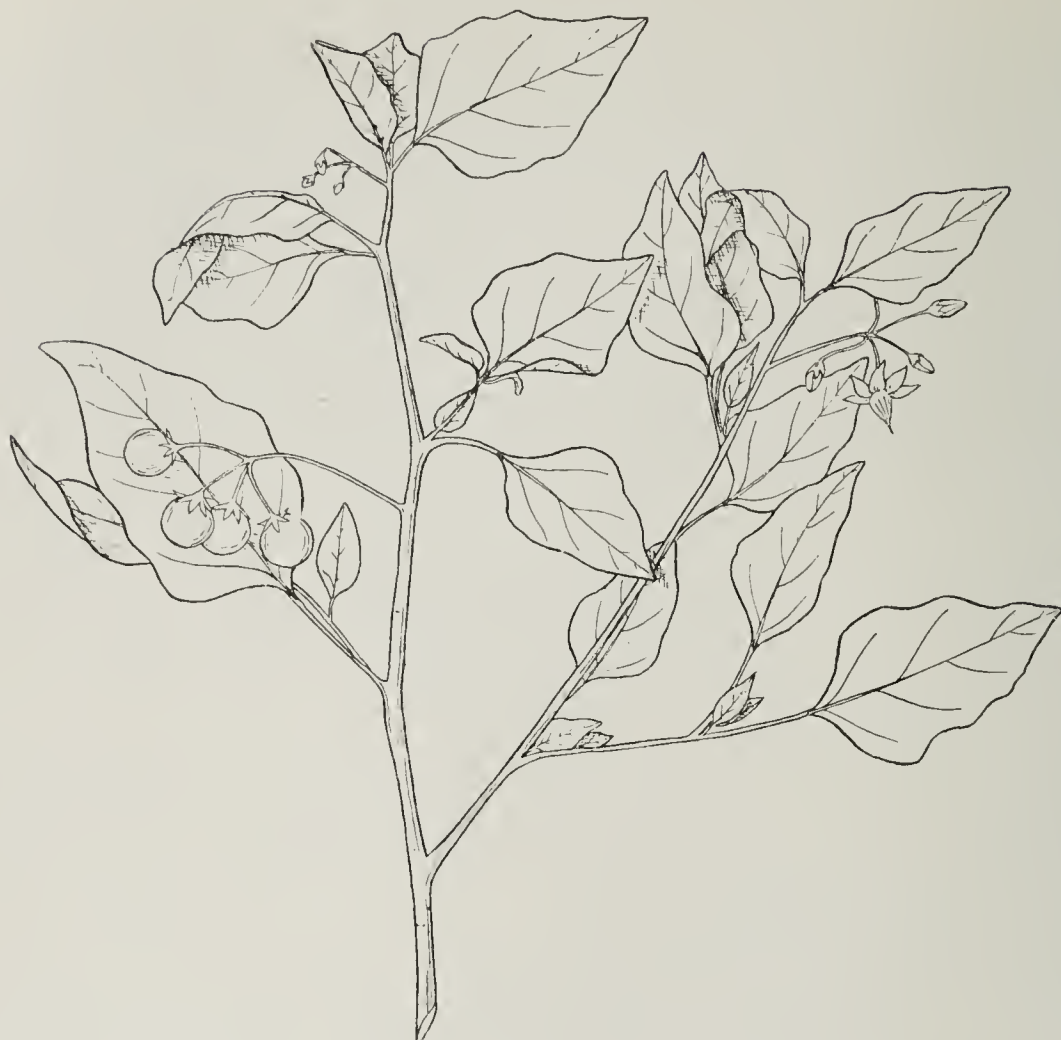


Fig. 83.—Black nightshade (*Solanum nigrum*).

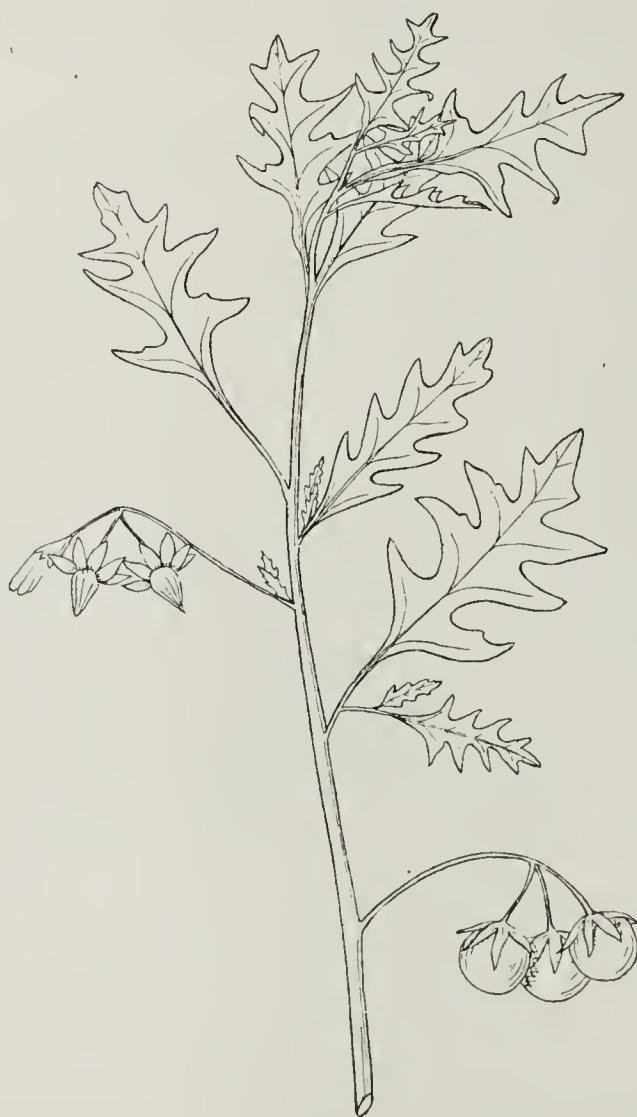


Fig. 84.—Three-flowered nightshade (*Solanum triflorum*)

hence the common name "three-flowered nightshade." The fruit is greenish, and about $\frac{1}{2}$ inch in diameter. The plant grows throughout the state from low altitudes up to 10,000 feet.

Poisoning by nightshades (Solanums).—The nightshade family is a large one and contains important medicinal plants and several important food plants. Many plants of the group have poisonous properties. Neither the black nor three-flowered nightshade are known to poison stock extensively. Bittersweet, sandbur, horse nettle, bull nettle and the common potato all contain poisonous properties. A large number of plants of this group contain the alkaloid *solanin*, and nightshade also has a bitter principle *dulcamarin* and two more alkaloids *solanidin* and *solanein*. The tops and sprouts of the common potato are poisonous when green. The tubers are poisonous when they have turned green from exposure to the sun. Hogs have been poisoned by eating raw potatoes that were wilted and beginning to rot; cases are reported every fall in the potato district in which horses and cattle have been poisoned from eating potatoes left in the fields after harvest. In one instance an entire herd of hogs developed paralytic symptoms after feeding for some time upon a ration consisting almost entirely of raw potatoes that were more or less withered and sprouting. The black



Fig. 85.—Sand bur, buffalo bur (*Solanum rostratum*).

and three-flowered nightshades are not a tempting food for animals, which fact no doubt accounts for their being rated of so little consequence as poisonous plants.

SAND BUR, BUFFALO BUR (*Solanum rostratum*)

A low annual plant, (fig. 85) yellowish-green in color. The stems, leaf-stalks, flower stalks, and main veins of leaves are armed with stiff yellowish prickles. The deeply-lobed leaves are covered with hairs arranged in small star-shaped groups. The flowers are about 1 inch in diameter and yellow in color. The mature fruit is very prickly. Buffalo bur is a plant of sandy plains.



Figs. 86 - 87.—Black henbane (*Hyoscyamus niger*) 86, leaves, pods, and fruit; 87, single pod, showing how it opens at the top by a lid.

Sand bur is not known to possess poisonous properties. The prickles on the burs sometimes cause serious mechanical injury.

BLACK HENBANE (*Hyoscyamus niger*)

This is a coarse biennial (fig. 86) plant 1 to 2 feet high. The leaves are wavy along the margin and clasp the stem. The flowers are large, dull yellow in color, with purple veins, and arranged along one side of the stem in a characteristic fashion. When the fruit is mature, it opens at the top by a lid (fig. 87). The plant has been found in a few localities in western Colorado. It is common in eastern states.

Poisoning by henbane.—Dr. Chesnut says of black henbane: "One or two cases are recorded in foreign literature in which stock have been poisoned by eating the plant of their own accord, but there is very little danger from it, on account of its ill odor and harsh texture." It is from this plant that hyoscyamin is obtained for medicinal use. It is an anodyne, hypnotic and is poisonous.

JIMSON WEED, JAMESTOWN WEED (*Datura stramonium*)

A rather stout plant (fig. 88) 1 to 4 feet high, with green stems, and leaves 4 to 8 inches long and angular toothed. The flower is showy,



Fig. 88.—Jimson weed (*Datura stramonium*).

white and about 3 inches long. The fruit is an oval capsule, beset with long, stiff prickles. The plant has been found in waste places at a number of low altitude points in eastern Colorado.

Poisoning by Jimson weed.—The poisonous alkaloids *atropin* and *hyoscyamin*, the active constituents of belladonna, are also found in the jimson weeds. Hyoscyamin is the poison found in henbane and the symptoms caused by it are the same as from atropin. There are a few instances recorded in which cattle have been poisoned by eating the leaves of young plants; with few exceptions, however, jimson weeds are rejected by animals.

THORN-APPLE, PURPLE STRAMONIUM (*Datura tatula*)

This is very similar to the preceding. It is distinguished from it by its purple flowers and purple stem. It is rare in this state. It is of little economic importance.

THORN-APPLE (*Datura meteloides*)

This plant often grows to be 3 or 4 feet high. The leaves are large, and wavy about the margin; the flowers are white, sweet-scented, 6 to 8 inches long, and the large, nodding pods are armed with short prickles. It is found along streams in southern Colorado, at low altitudes. It is suspected of being poisonous to animals.

WOODY ASTER (*Xylorhiza parryi*)

Although this plant (fig. 89) has not been reported from Colorado, it may be looked for in the northern part of the state. It has been identified in Wyoming as the cause of the death of sheep. Herewith follows a description of the plant as taken from Bulletin 97, Wyoming Agricultural Experiment Station:

"This plant has a strong woody root more or less branched just at the surface of the ground. From these woody crowns tufts of



Fig. 89.—Woody aster (*Xylorhiza parryi*).

short branches spring. These bear green, narrow leaves, 1 or 2 inches long, the whole tuft becoming at length several inches high, and finally producing in June, a considerable number of large, white, daisy-like flowers with a yellow center. If the leaves be examined it will be found that they usually bear a considerable number of yellowish or brownish spots caused by a fungus."

The plant begins to leaf out about May 1, and to blossom about June 1. It grows upon gumbo clays such as are frequently found about lakes and ponds.

Poisoning by woody aster.—This plant is looked upon as the most disastrous plant for sheep in Wyoming. In Bulletin No. 88 of the Wyoming Experiment Station, the statement is made that stockmen estimate their losses at 14.6% and: "In terms of the last assessment valuation of sheep in Wyoming, this means an annual loss of more than \$3,000,000. Sheepmen who have followed the business for the past ten years estimate that of the total losses noted, 60-70% have been caused by poisonous plants, and the remainder by coyotes." This bulletin summarized the investigation of woody aster partly as follows.

1. The woody aster has been proven to be poisonous to sheep.
2. The woody aster grows only on alkali-ed gumbo-clay soils, and but for the one recorded season, is always heavily infested with the fungus, *Puccinia xylorrhizae*. The presence of the fungus may add to the poisonous character of the plant.
3. Ninety to one hundred percent of the animals affected die.
4. Aster poisoning is characterized by lassitude, difficult respiration, muscular weakness, bloat, and final prostration.
5. Duration of illness: from a few hours to several days.
6. Treatment: purely symptomatic and none uniformly successful.
7. Prevention: avoid aster patches.

SNEEZEWEED

The name "sneezeweed" is applied to several species, the principal ones being *Helenium autumnale* and *Dugaldia hooperii*.

Helenium autumnale (fig. 90) is a perennial, erect herb 1 to 3½ feet tall. The leaves are lance-shaped, slightly toothed along the margin; they clasp the stem, their lower edges being continuous with two wings that run down the stem. There are numerous yellow flowers of the sunflower type. The plant grows in wet ground and has been reported from a few localities in the state.

Dugaldia hooperii is a stout plant 1 to 3 feet tall, woolly-hairy, especially above. The stem is leafy, the leaves spatula-shaped, and 3 to 4 inches long. The flowers are of the sunflower type, and yellow in color. The plant is found in the mountains from 7,000 to 12,000 feet throughout the state.

Poisoning by sneezeweed.—Sneezeweed contains a narcotic poison, and cattle, horses and sheep are no doubt occasionally poisoned by it. Dr. Chestnut says: "The fine-leaved Sneezeweed has been reported from several of the Gulf states, where it is a troublesome weed, fatal to horses and mules. It is not known to what extent cattle may

feed upon it with impunity, but the bitter principle in milk and meat sometimes met with in the Southern States is quite generally supposed to be due to these plants."

In the mountainous districts of Colorado, bitter milk and meat are not uncommon, and it can no doubt be safely attributed in many instances to the eating of this plant. Severe poisoning may result from eating large quantities of the plant.



Fig. 90.—Sneezeweed (*Helenium autumnale*).

SAGE (*Artemisia*)

There are many different kinds of sages growing in the state. Rydberg's "Flora of Colorado" gives 39. A number of these are rare. The "sage brush" (*Artemisia tridentata*) of Colorado is a shrub 2 to 12 feet high with silvery leaves that have three characteristic teeth or lobes at the tip. The common low silvery herbaceous sage throughout the state from low to high altitudes is *Artemisia frigida*. The foliage of this is very finely divided.

Poisoning by sage.—Western stockmen testify to the poisonous qualities of sage, and animals that have become affected by it are

spoken of as "saged." Horses are mostly affected and the most pronounced symptom is a growing paralysis of the hind quarters. Some stockmen, with many years experience, avow that eating sage is fully as disastrous to their herds as are the loco weeds. The evidence of so many experienced stockmen is not to be wholly discredited and this subject is worthy of further investigation.



Fig. 91.—Rubber plant (*Hymenoxys floribunda*).

COCKLEBUR (*Xanthium echinatum*)

Cocklebur is an annual plant with thick stout stems that branch widely. The stem is often marked with dotted brown spots. The leaves may be oval in outline, or heart-shaped at the base, and usually have 3 main ribs. Stamens and pistils are in different flowers on the same plant. Cocklebur is best recognized by the spiny fruit. The "burs" are densely covered with long prickles. At the tip of the "bur" are usually two stout hooked prickles.

The plant is weedy in nature and may be found throughout the state at low altitudes.

Poisoning by cocklebur.—Dr. Pammel in his Manual of Poisonous Plants makes the following statement: "The injury from this plant probably comes largely from its mechanical action. Stock will probably not eat very much of it, but on account of the hooked awns of the involucre the animal may have a considerable difficulty in removing them. The hairs of the plant cause itching. The plant contains the poisonous glucoside *xanthostrumarin* which resembles *datiscin*." According to Chestnut, the young seedlings of three species of cocklebur are poisonous for hogs. Dr. Bitting thinks the injurious properties are largely mechanical.

COLORADO RUBBER PLANT (*Hymenoxys floribunda*)

This is an herb (fig. 91) with an aromatic odor. Numerous stems arise from a woody base to a height of about 1 foot. The stems at the base are covered with woolly hairs. Each main stem is branched near the tip, each smaller branch being terminated by a yellow flower. The leaves are divided into several very slender divisions. The plant is found in dry soil at an altitude from 4,000 to 10,000 feet.

Poisoning by rubber plant.—Reports of serious losses in sheep from eating the rubber plant have come from Durango, Saguache and Middle Park. The plant is not known to contain any poison; the injurious effects are probably mechanical. It is thought that death results from the formation of indigestible masses that obstruct the digestive tract. On the ranges west of Saguache this is considered a most dangerous plant for sheep and they are systematically herded away from rubber weed patches.

ACKNOWLEDGMENTS

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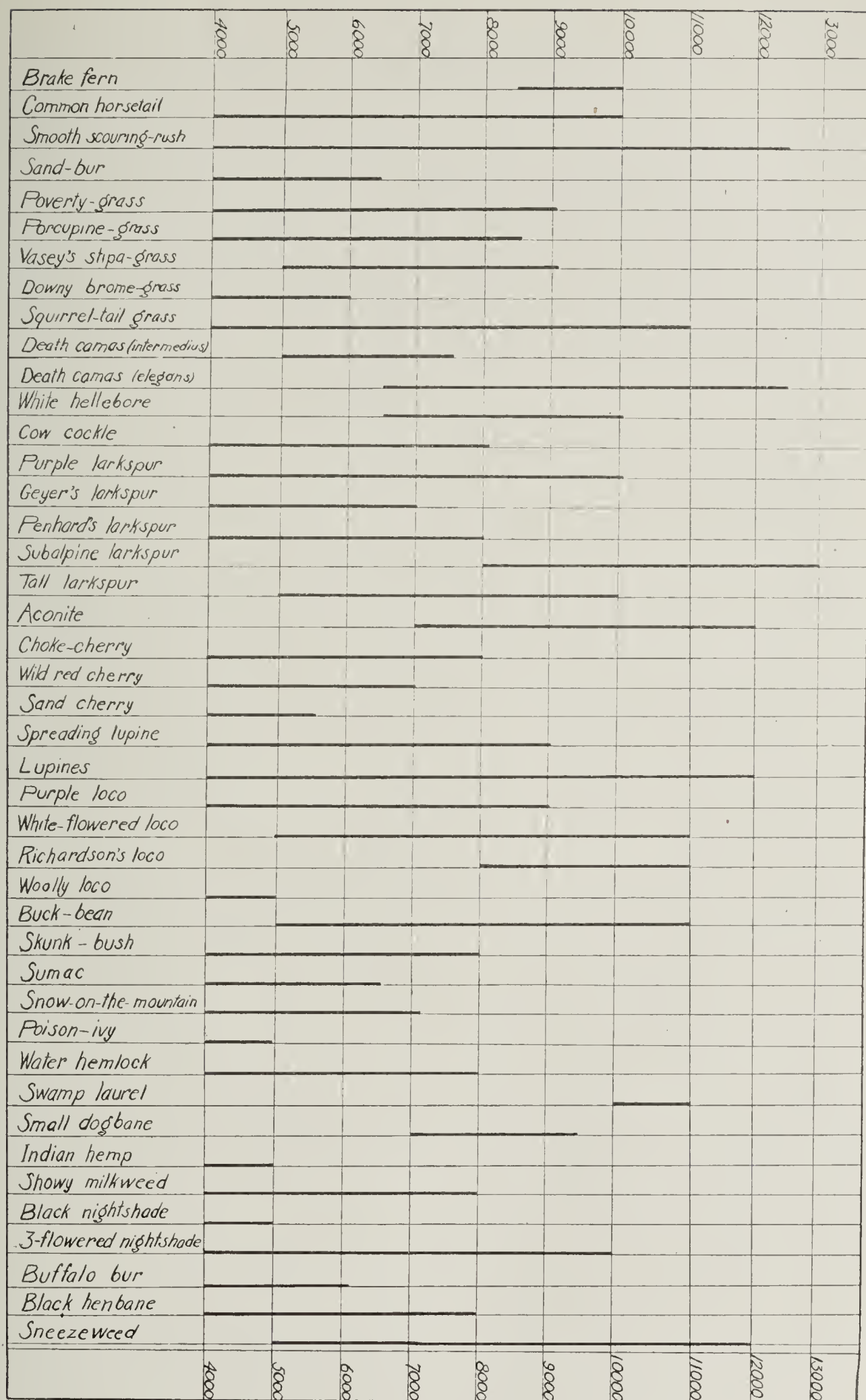


Fig. 92.—Altitudinal distribution of important plants injurious to livestock.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

FUNGOUS DISEASES OF COLORADO CROP PLANTS

By

WILFRED W. ROBBINS and OTTO A. REINKING



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FUNGOUS DISEASES OF COLORADO CROP PLANTS

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INTRODUCTION.

Colorado crops, of orchard, garden and field, are not troubled with as many fungous diseases as are those of the states to the east and west which have a moister climate. Colorado's comparative freedom from fungous troubles causes frequent comment from those who are familiar with conditions as they exist in the east. Such destructive diseases as bitter rot of apple, brown rot of stone fruits, peach leaf curl and late blight of potato do no injury to crops in Colorado.

The direction of migration of economic plant diseases follows rather closely the direction of migration of man himself. Man is the chief agent in the spread of disease from one locality to another far distant. Prior to 1888, one finds little recorded mention of plant diseases within Colorado's borders. And we have reason to believe that up to that year and even up to several years later, fungous diseases of cultivated plants in Colorado were largely unknown or not serious enough to attract much attention. Today many diseases have permanently invaded the state. This has been due to more intensive cultivation in the state, to an introduction of a greater variety of host crops, and (until a few years ago) to a lack of proper inspection laws.

Crandall writes in 1891: "In all localities east of the mountains there is yet entire freedom from fungous diseases, with the exception of the occasional appearance of plum pockets on native wild varieties. The bacterial disease, variously known as 'pear blight,' 'apple tree blight,' 'twig blight,' is prevalent, and in some sections has done great damage. In the western districts diseases and insect troubles are at present unknown, but it can hardly be hoped that the immunity now enjoyed will continue. Growers in that district should prepare themselves to profit by the experience gained elsewhere and meet the first attacks with determined efforts at extermination." This was in 1891. Some years later, in 1898, Crandall (Crandall, C. S., 11th Annual Report Colo. Exp. Sta. for 1898) reports as follows: "Colorado orchards have in past years been free from fungous diseases, but the diseases which have given the eastern growers trouble are gradually coming in and

there is a rapidly growing interest in them among the fruit growers."

The first disease to attract attention in Colorado was the twig blight of pear and apple. In 1888, Cassidy (Cassidy, James, "Apple Twig Blight," 1st Annual Report Colo. Agr. Exp. Station, pp. 64-70, 1888) reported this disease near Fort Collins, as appearing in the latter part of June and continuing until late in August. He considered this trouble on the apple to be identical with fire blight of pear and a similar trouble on Lombardy and other species of cottonwood. Blight of pear and apple has become increasingly serious throughout Colorado. In 1891, Crandall (Crandall, Chas., "A Preliminary Report on the Fruit Interests of the State." Bull. No. 17, Colo. Agri. Exp. Sta., 1891) comments that the "bacterial disease variously known as 'pear blight,' 'apple tree blight' and 'twig blight' is prevalent and in some sections has done great damage." In 1898, (Crandall, C. S., "Blight and Other Plant Diseases," Bull. 41, Colo. Exp. Station, 1898) Crandall indicates that the disease had brought numerous inquiries to him. We judge from this that it had become more widespread. Paddock (Paddock, W., 22nd Annual Report State Board of Agriculture, 1900) reports a body blight of apple and pear known in some localities as "crater blight." This is now considered to be due to the organism causing fire blight. In 1903, Paddock (Paddock, W., Bull. 84, Colo. Exp. Sta., 1903) showed that apricot blight was the same as pear blight. It seems well established now that the bacterial organism, *Bacillus amylovorus*, may cause a blight on pear, apple, quince, apricot and plum, known by such common names as pear blight, fire blight, twig blight, apple blight, blossom blight and body blight. From the foregoing brief historical sketch of pear blight in Colorado, we see that since its appearance in 1888, it has become more widely spread in the state and its attacks have increased in severity.

The history of potato diseases in Colorado is as instructive as that of pear blight. The first mention of potato troubles in Colorado is found in a publication by Paddock and Rolfs, (Paddock, W., and Rolfs, F. M., "Potato Failures," Bull. 64, Press Bull. No. 8, Colo. Exp. Sta., 1901) in 1901, in which they call attention to potato failures in various sections, due probably to *Rhizoctonia*. They indicate that this disease has "undoubtedly been present in our potato fields for a long time." They say that little blight (*Fusarium*) is in evidence. In 1902, Rolfs (Rolfs, F. M., "Potato Failures," Bull. 70, Colo. Exp. Sta., 1902) published a preliminary report on *Rhizoctonia*, describing the occurrence and effects of the disease on the potato, the nature of the fungus, and giving the results of inoculation and preventive experiments. This is our first valuable

account of *Rhizoctonia* in Colorado. In 1904 (Rolfs, F. M., "Potato Failures," Bull. 91, Colo. Exp. Sta., 1904) Rolfs published further notes on *Rhizoctonia*, in which he gives additional information relative to the life history of the fungus, its injuries, spread, and remedial measures.

The first mention of potato blight (*Fusarium*) is found in a press bulletin by Paddock in 1906 (Paddock, W., "Potato Problems," Press Bulletin No. 26, 1906). Within the last few years, and particularly during 1911 and 1912, *Fusarium* has seriously crippled the potato industry in many parts of the state. It is doubtful, however, if the organism, *Fusarium oxysporum*, is responsible for all the potato troubles in districts suffering.

Other potato diseases such as early blight, internal brown spot, and potato scab have not developed in severity as have *Fusarium* and *Rhizoctonia*. Both of the latter diseases have made remarkably rapid progress in the state. This is largely due to the general practice of growing potatoes continuously year after year on the same soil. Colorado potato failures, although lamentable, have been a blessing in disguise. They have brought forcibly to our attention the necessity of a proper system of crop rotation and the more general adoption of diversified farming. Crop rotation is a highly reliable practice in the control of a great majority of diseases of field and garden crops.

It is well that we keep on the watch for the first appearance of fungous diseases in the state. In many instances, the immediate suppression of a disease that has just been introduced may mean the saving of thousands of dollars to an entire community. Fungous diseases fluctuate in prevalence from year to year, largely depending upon climatic and weather conditions. If a disease is very bad one year, the chances are that there will be an abundance of infection material near at hand the following season. However, it sometimes happens that a serious outbreak is followed by a year of comparative freedom from disease. On the other hand, a serious outbreak may follow a year during which little disease was present.

The Department of Botany of the Experiment Station will be ready at all times to identify promptly plant diseases that are sent in, and suggest remedies.

DISCUSSION OF CHIEF FUNGOUS DISEASES

ALFALFA.

BACTERIAL BLIGHT.—Diseased plants are stunted and lighter green in color than normal. Stems chiefly infected. Infected portions at first are water-soaked in appearance, and olive green in

color. Small drops of a sticky amber liquid, which soon dries with a glistening finish, later turning brown and then black, may collect over diseased portion. In advanced stages, the stems shrivel, become brittle, turn black, and die. Diseased leaves show a water-soaked appearance and an orange yellow coloration along the leaf-stalk and midrib. Later, they dry up and become brittle. On one-year-old plants, the whole crown may become infected, turn black, and die. The disease is caused by a bacterium which attacks the first crop only and then lives over until next season in the soil and on old stems. In years when late frosts are prevalent, the disease is most severe.

Control—As soon as danger from late frosts is past, clip the frosted alfalfa. By so doing, the stems split by freezing and hence subject to attack by the causal bacterial organism will be removed and new sprouts given a chance to grow.



Plate I. Alfalfa leaf spot.

DOWNY MILDEW.—This disease has become increasingly abundant in Colorado, since it was first noticed in 1906. However, it has not become serious, except in a few localities. The leaves at tips of branches are usually attacked, turning yellow-green or yellow-gray to purple. A fuzzy growth develops on the under side of the leaf, which is grayish at first, and later violet.

Control.—Do not irrigate excessively. Do not crowd plants, as it makes them more liable to attack.

LEAF SPOT.—The disease first attacks lower leaves. Diseased spots are local, brown to black or yellow, circular, and with irregular edges (Plate I). Affected leaves usually turn yellow and drop prematurely. The trouble occurs in both old and new fields, and under very different soil conditions.

Control.—Since alfalfa leaf spot is widespread and easily disseminated, control-measures are not entirely satisfactory. If disease is serious, mowing of infested field when leaves begin to turn yellow will hold the disease in check.

APPLE.

FIRE BLIGHT.—See Pear, page 34.

APPLE ROT—BLACK MOLD.—The fruit is attacked usually at the blossom end. Spots are formed which at first are small, dark purple-brown, and slightly sunken (Plate II). Affected tissue is



Plate II. Apple rot or black mold.

not greatly softened. In severe cases the apple becomes a shriveled, dark-brown mass. When the apple is placed in storage, the spot increases in size, and sometimes involves the entire fruit. The disease often gains entrance to the fruit by means of wounds. Frequently, no external evidence of the trouble is noticeable, but when

the apple is cut through, the core cavity and seeds are found to be blackened, and in severe cases the surrounding flesh may be discolored.

Control.—(1) Sanitation. Diseased fruit should be either collected from the ground in the fall, or plowed under. Trees should be kept in good health.

(2) Spray with Bordeaux 4-5-50, or lime-sulfur, just before the buds open in the spring.

(3) Avoid injuring fruit before placing in storage.

CROWN GALL.—Galls may appear on root, stem, or leaf. In orchard fruits, they are most common at the crown, forming there, large warty swellings (Plate III). There are two types of galls,



Plate III. Crown gall on a six-year-old plum tree. The warty growth is hard and woody.

soft and hard. Soft galls usually decay at the end of the season; the harder types may persist for years. Hairy root, a form of crown gall, is characterized by excessive production of fibrous roots.

Control.—(1) Plant only disease-free stock. Burn all infested nursery trees.

(2) Avoid unnecessary injury to plants.

BITTER PIT.—A non-parasitic disease, also known as “Baldwin-spot” and “brown-spot.” Spots on the surface are more abundant near the blossom end. They are small, sunken, and various shades of brown. Affected areas may be scattered throughout the apple tissue nearly to the core. The disease may appear before maturity, but develops more often in storage.

Control.—(1) Spotting of susceptible varieties cannot be entirely prevented.

(2) Fruit should be stored in dry air at a low temperature.

JONATHAN SPOT.—The spots, which are distributed over the apple surface, are usually only skin deep, irregularly circular, brown to almost black, and usually somewhat sunken. The disease is not confined entirely to the Jonathan, but develops on other varieties. It is produced only on matured fruit and is most severe in storage and after taken out of storage.

Control.—Cold storage greatly retards development.

POWDERY MILDEW.—This occurs on leaves and twigs. On the leaf, light powdery patches are produced. These are more common on the under surface, but sometimes on both. The patches are small at first, but later increase in size until the entire leaf is covered. In severe cases, affected leaves are crinkled, dwarfed, and drop off. Twigs are stunted or even killed in the worst cases. Powdery mildew does the most injury to nursery stock.

Control.—(1) Cut out and burn infected twigs if the disease is severe.

(2) Spray with Bordeaux mixture or lime-sulfur, immediately after petals fall and later at intervals of two to four weeks, depending upon severity of disease.

RUST.—One stage of this disease is found upon the cedar and another upon the apple. The leaf, fruit, and young twigs of the apple may be affected. The spots on the leaves and fruit are at first about the size of a pin-head, and pale-yellow in color. Later, long cylindrical-shaped organs project from the surface (Plate IV). Fruit may be dwarfed or deformed as a result of the infection.

On the cedar, the diseased condition is known as a “cedar apple.” The cedar apple is an enlargement of the leaves and twigs of the ordinary red cedar. These enlargements may be one-half to two inches in diameter. In the winter the gall-like structure is hard



Plate IV. Pear affected with rust. The appearance of the disease on the apple fruit is similar. Note the long cylindrical-shaped bodies projecting from the surface.

and woody, but in the spring may become swollen and gelatinous. Numerous finger-like gelatinous outgrowths are formed following a rain. Spores from the cedar apple infect the apple, causing the well-known rust upon it.

Control.—(1) Where practicable, remove all cedars in the vicinity of orchard.

(2) Some varieties of apples are comparatively rust resistant, for example: Winesap, Grimes Golden, Yellow Transparent, Ben Davis, Red Astrachan, Duchess, and Maiden Blush. The following are most susceptible: Wealthy, Jonathan, Missouri Pippin, Whitney, and Red June.

APRICOT.

BLACK KNOT.—See Plum, page 37.

CROWN GALL.—See Apple, page 12.

ASPARAGUS.

RUST.—Asparagus rust attacks the tall, branching plants that come up after the cutting season. The plant is hindered in its food-making process, and consequently the underground stems do not receive the normal amount of stored material. As a result, they lack the strength to send up a good crop of “spears” the following spring. The rust appears as small lengthened spots on stems and leaves. The spots look like blisters at first, then they break open

and appear powdery. The spots that make their appearance in July and August are rusty in color, while those that come in September and October are black.

Control.—(1) Dry sulfur:

- a. Use a finely pulverized sulfur, preferably "*flowers of sulfur*," rather than "*flour of sulfur*." ("Flowers of sulfur" is a fine grade that has been sublimed. It sometimes goes by the name of "atomic sulfur." "Flour of sulfur" is a cheaper grade of ground roll sulfur.)
- b. Make first application to plants at rate of 150 lbs. per acre, about three weeks after the last cutting of sprouts. Follow with another application at rate of 100 lbs. per acre in about one month.
- c. Apply sulfur only in early morning when plants are covered with dew. The sulfur must stick to the plant.
- d. On small patches of asparagus, the sulfur may be sprinkled on with ordinary large pepper box. On large patches use some form of bellows-blower.

(2) Spores are carried over winter on diseased stalks and on ground surface. Late in fall, cut and burn the diseased stalks in the field where they have fallen. Further, in order to insure the killing of spores on the ground, put a light covering of straw on the asparagus bed, and burn.

(3) Select disease-resistant varieties. Palmetto is very resistant to asparagus rust.

(4) Plants that have a good supply of water and are well cultivated, and as a result, are making a strong, vigorous growth, are less liable to attacks of rust than plants poorly cared for and deprived of water.

(5) Asparagus escapes from cultivation and frequently becomes common along fences. Unless such stray plants are destroyed, they may be a source of rust infection.

BEAN.

BACTERIAL BLIGHT.—This occurs upon the pod, leaf, and stem of common and Lima beans. The leaves are usually the first to be attacked. At first there appear large, watery patches that are brown in color. Later these patches dry up, becoming papery and brittle. Hence the leaves curl and become ragged in appearance. Pods are most severely attacked. On these, the spots are small at first, but spread rapidly into large, watery areas with indefinite pink or reddish-brown borders. In time, the pods rot. Infected areas on the stem are similar to those on the leaf. The disease is carried over on infected seed. It is spread in the field by insects.

Control.—(1) Select seed from healthy pods only, grown in fields that are not infected.

(2) New lands should be used when available, and crop rotation should be practiced.

(3) In severe cases spray with Bordeaux mixture, 4-5-50 formula.

a. First spray, when plants are 2 to 3 inches high.

b. Second spray, ten days later.

c. Third spray, after blossoming.

(4) Any measure that will check ravages of insects is advised.

ANTHRACNOSE.—The disease is found on all parts of the bean plant above ground. One is usually attracted by the spots on the pods (Plate V, Fig. 1). These are, at first, small and dark-col-



Plate V. Fig. 1. Anthracnose of bean. Fig. 2. Late blight of celery.

ored. They increase rapidly in size up to a quarter-inch or more. Spots may run together and cover the greater part of the pod. They are round or oval, sunken, nearly black, or at times pinkish, and usually surrounded by a reddish zone. On the leaves the spots are found mostly on veins and stem. The spots of the seed are located directly under pod spots.

Control.—(1) Use seed from healthy pods only, preferably those grown on fields known to be free of the disease.

(2) Burn infected material.

(3) Rotation of crops is important.

(4) Spray with 4-5-50 Bordeaux first, as soon as the plants are up, then about ten to fourteen days later, and again when the pods are forming.

BEET.

ROOT ROT (*Rhizoctonia*).—The outer leaves are first attacked at the base, turn black and droop. The disease spreads into the crown of the beet, which turns brown, cracks, and in time may rot away. The trouble spreads rapidly from plant to plant. Young plants are also frequently attacked by the root rot fungus.

Control.—(1) Keep soil well aired by good cultivation.

(2) Rotate crops.

SOFT ROT.—This is a bacterial disease. The lower end of the root decays, the rotted portion being honeycombed. The cavities of this portion are filled with a rather sticky, colorless, sour-smelling liquid. The upper part of the root, the crown, and leaves, are not affected, and hence the plant maintains a normal color and form above ground. Young plants are not attacked seriously.

Control.—(1) It is useless to spray.

(2) A wet, poorly drained soil favors the development of disease. Improve soil conditions.

LEAF SPOT.—This disease attacks the outer, older leaves first. The youngest leaves in the center rarely show the spots, and the beet plant is seldom killed. At first the spots are tiny white points scattered over the leaf surface. They gradually increase in size, become round, show a distinct line between diseased and healthy portion, and assume a brown color frequently tinged with a red-brown or purple. Still older spots assume an ash-gray center. They are usually distinct, but may become numerous enough to cover the entire leaf. Such a leaf blackens and dies. As the older leaves die, new leaves are formed at the center of the crown. Hence, there is formed an elongated crown with tufts of small green leaves at the top.

Control.—(1) Deep fall plowing and crop rotation is the most satisfactory method of control.

2. Spraying with Bordeaux mixture, 4-5-50 formula, will almost perfectly control the disease, but it is seldom practical. The time for spraying is indicated by the first appearance of the disease. The leaves must be covered thoroughly on both sides.

(3) A proper and uniform supply of moisture in the soil is beneficial.

(4) If cattle or sheep are used in pasturing the tops, care should be taken that no diseased leaves are scattered to fields intended for beets the following year. Do not allow livestock to enter fields to be used for beets the following year until several days after they have been taken off from the beet-top pasture. The spores of the leaf spot fungus pass through the alimentary canal of cattle uninjured.

(5) Beet tops should be plowed under in the fall, to a depth of ten inches or more.

(6) Manure from stock fed with diseased beet tops should be applied to the land one or two years in advance of the beet crop.

ROOT KNOT.—This trouble is caused by minute worm-like animals (nematodes) which are invisible to the naked eye. It is often mistaken for a fungus trouble. No deformities are produced on the beet above ground. Badly infested plants are dwarfed, wilt easily, and are usually a pale green. In severe cases, the plant may be killed. Galls may form on fine feeding roots, or on larger roots. These enlargements are scattered, or close together and produce abnormal thickening of the root system. In severe cases the roots are a swollen mass.

Control.—(1) Rotation of crops. Cultivate immune crops for two or three years. Kill all weeds and other plants in which the worm-like animals live. Plants not attacked are barley, corn, broom corn, millet, red top, rye, sorghum, timothy, wheat, and winter oats.

(2) Prevent running water, implements, animals, etc., from bringing the nematodes from near-by infested fields.

(3) Starving the parasite by keeping the land free from all vegetation for two years is an effective control method, though often impracticable.

CROWN GALL.—The crown gall of beet is caused by the same organism which produces galls of the apple. The characteristic swellings or galls may be produced upon any portion of the beet root. See crown gall on apple.

Control.—Rotation is the only effective remedy if the bacteria once gets into the soil. Plants which are not attacked, like the grains or grasses, should be used in the rotation.

BLACKBERRY.

LEAF SPOT.—Diseased spots are small and numerous. They have a white or ashy-gray center, bordered with a brown or reddish ring. In later stages, minute black specks may cover the center of

each spot. This disease is not very common and epidemics are rarely developed.

Control.—See anthracnose of currant.

ORANGE RUST.—See Raspberry, page 45.

ANTHRACNOSE.—See Currant, page 29.

CABBAGE.

CLUB ROOT.—This is an uncommon disease in Colorado. It occurs on cabbage, radish, turnip and other members of the mustard family. The roots of the infected plants become greatly swollen and contorted, usually forming a cluster of finger-like or spindle-shaped swellings. Wilting of the plant results, particularly on hot days, although in the early stages of the disease such wilted plants may recover at night. Later, the plant succumbs or forms only a small head. The organism causing the trouble is in the soil and first attacks the young roots.

Control.—(1) The disease may be carried from field to field in the soil on the feet of horses, or on cultivators. Diseased plants thrown on the manure pile or compost heap may subsequently reach the field. Precautions should be taken to burn all affected plants.

(2) Rotation of crops.

(3) Destruction of weeds of the mustard group that may harbor the fungus.

BLACK ROT.—This is a bacterial disease. Infected plants are dwarfed, and often one-sided. In severe cases the entire head fails to develop or the plant dies. A black ring, corresponding to the woody part of the stem, is found in cross-sections of affected stems. This blackened tissue often can be traced up into the head. Infection takes place at the leaf margin or about insect wounds. The leaf veins become blackened as the disease progresses. The tissue between the leaf veins turns yellow and then brown. Affected leaves dry up and drop prematurely, thereby producing an elongated stem covered with leaf scars. Diseased leaves pulled from the stem show blackened bundles in the leaf stalk.

Control.—(1) Disinfect the seed, before sowing, in corrosive sublimate, 1-1000, for fifteen minutes, or in formalin, 1-200, for twenty minutes.

(2) Prepare seed-bed with manure and soil that is free from diseased refuse.

(3) Crop rotation is very important. No cultivated crucifers or cruciferous weeds should be allowed to grow in the ground for four or five years after a bad attack.

(4) Keep down insects, slugs, snails, etc., for they spread the disease from plant to plant.

(5) Do not allow livestock to roam over infested fields, for they carry the organisms to non-infested fields.

(6) Diseased plants should be pulled up and destroyed.

CANTALOUPE.

LEAF BLIGHT OR "RUST."—This disease is more properly termed "blight." The name "rust" is suggested by the rusty appearance of the leaves due to the numerous brown spots with which they are covered. These spots are circular; they first appear on leaves in the center of the hill. They may enlarge as the disease progresses, and several may run together, causing a curling and death of the leaf. Frequently the disease occurs on stems. Moist weather favors the spread of blight. Affected plants ripen their fruit prematurely, thus destroying the flavor.

Control.—(1) Use resistant varieties.

(2) Rotation of crops. This is highly advisable.

(3) Spray with 4-5-40 Bordeaux, first when the vines begin to run, followed by 1 or 2 more at intervals of 10 to 14 days.

CARROT.

SOFT ROT.—This is a bacterial disease which causes a soft rot of many vegetables. Decomposition usually begins either at the crown or root tip, and progresses rapidly through the core. Bacteria enter the fleshy tissue through wounds. Lengthwise sections of diseased roots show a softened, watery, decayed portion which is usually brown. There is a sharp line of division between the decayed and sound tissue.

Control.—(1) Treatment must aim entirely toward prevention.

(2) Rotation of crops is advised, with such crops as the grasses, cereals, etc.

(3) Use manure that is free from refuse of diseased plants.

(4) Dry the root surface before storage. The roots should be left on the surface of the ground, exposed to the sun, a few days before storage. Store in a dry and well ventilated place. The organism cannot endure drying nor can it invade dry tissue.

(5) Cold storage is advised at a temperature between 39 and 50 degrees F. This temperature, coupled with the disinfection of the root surfaces by drying and sunlight, should prevent serious injury from the rot.

CELERY.

BLIGHT.—There are two distinct blights of celery, *early blight* and *late blight*. Both diseases are due to fungi which feed upon the leaves, and in some cases the stems. The organisms causing the two diseases are entirely different. The effects of, and the remedial measures for the two are similar, however.

Early blight may make its appearance in the early stages of the plant's growth, either in the seed-bed or in the field. The outer leaves are first attacked; grayish-green spots, roughly circular in outline and with slightly raised borders, appear. Later the spots become darker in color, an ashen-gray, and larger. In some cases several adjacent spots may run together. Finally the entire leaf withers and dies. When the spots become brownish, it is an indication that they are producing reproductive bodies, the spores. These are readily blown from plant to plant, and in this way the trouble is spread throughout the field.

Late blight, in general appearance, resembles early blight (Plate V., Fig. 2). It may follow early blight in the same field and its effect upon the marketable value of the celery plant is similar. As compared with the early blight, the spots on the leaves are more irregular, and yellowish in color rather than ashen-gray. The spots later become covered with small, black fruiting bodies. These are readily seen with the hand lens. Late blight is found in the field until the plants are lifted and commonly continues its destructive work in storage. In fact, often the worst damage to the celery crop from late blight comes while the plants are in storage.

Control.—(1) Do not set plants from the seed-bed that are the least spotted.

(2) Dip leaves of all transplants in a weak solution of ammoniacal copper carbonate.

(3) Keep the plants in as vigorous condition as possible from start to finish. This is important.

(4) Remove and burn all diseased leaves, if practicable, as fast as they appear, so as to prevent further spread of the disease.

(5) Remove and burn all celery debris from the celery plot in the fall; this debris may harbor the spores which will live over the winter to infect young plants the following spring.

(6) Spray with ammoniacal copper carbonate, or 5-6-50 Bordeaux mixture, first when the plants are in the seed-bed, following with treatments at two or three week intervals throughout the growing season.

(7) In the case of late blight, dip only the leaves of lifted plants into ammoniacal copper carbonate before placing in storage.

(8) Do not store plants that show any spotting.

(9) The celery leaf spot disease may be spread by the use of affected seed. To render the seed safe, soak them three hours in formalin solution (1 pint 40 per cent formalin in 70 gallons of water). Thoroughly dry seed before planting.

CEREALS.

RUSTS.—The cereal rusts are too well known to need description. They occur on both stems and leaves, and in many instances cause serious injury to the crop.

Control.—There are no satisfactory, practical methods of control. Some varieties are more rust-resistant than others. It appears that plants growing on soil that is well-drained are more resistant to rust than plants on poorly-drained soil.

BARLEY.

COVERED SMUT.—Smut masses enclosed by thin covering, which breaks open soon after heads appear. Smutted grains (“smut-balls”) often occur in threshed grain. Chaff as well as grain is smutted. Spores are blown from infected heads to healthy grain. These spores remain over winter on the outside of the healthy grain.

Control.—Use the formalin sprinkle as given under bunt of wheat.

LOOSE SMUT.—Smut masses not enclosed for any length of time by thin covering. As soon as smutted heads appear, the spores are scattered by the wind, and nothing but the bare stalk of the head remains. “Smut-balls” not formed. Smut mass olive-green in color. Appears earlier in season than covered smut. It is the more common sort of barley smut with us. Infection of sound seed always takes place before harvest time. The smut is carried over within the seed, not on the outside, as in the case of covered smut of barley.

Control.—Use *hot water* method as described under loose smut of wheat. *Note:* In the case of barley, the water in Tub No. 2 is kept exactly at 125 degrees F., and the grain is left in it 15 minutes.

WHEAT.

STINKING SMUT, OR BUNT.—Bunt is the most destructive smut of wheat. It is more common than loose smut of wheat. Bunt is exclusively a kernel smut. The contents of the grain of wheat are entirely replaced by a powdery mass of black spores. The spore mass or “smut-ball” is rather hard. Bunt usually is not noticed until the heads are mature. As a rule, all grains of a head, and all heads of an infected plant are smutted. Smutted grains, as compared with healthy ones, are darker in color, lighter in weight, plumper, and more easily crushed. When the smutted grain is crushed, numerous black spores are liberated, and the grain gives off a characteristic decayed fish odor. The spores get on healthy grain usually at threshing time; the smut-balls are

crushed in the thresher. A few broken smutted seeds can contaminate a large amount of healthy grain. Spores are carried from farm to farm by threshing machinery, and by wind. Bunt affects both spring and winter varieties of wheat. The spores of bunt will not cause smut in oats, barley, corn, or sorghum. The smuts of these cereals are distinct.

Control.—The object of seed treatment is to kill all bunt spores clinging to the outside of healthy grains. Bunt spores are carried into the ground with the grain of wheat, the young seedling is infected and at maturity the heads of the plant are smutted. Before treating seeds with formalin, place them in a tub or barrel of cold water, and stir. The lighter smutted grains will come to the top and may be skimmed off. Smutted seeds may also be fanned out with a good fanning mill. The easiest and most efficient seed treatment is the *formalin sprinkle*. This is done as follows:

(1) Formalin is a solution of formaldehyde gas in water. It usually has a concentration of about 40 per cent. Ask for this strength. Formalin may be obtained of any druggist. Put 1 pint (1 lb.) of formalin in 45 to 50 gallons of water. Stir thoroughly. Use this material when fresh; it deteriorates with standing.

(2) Put seed wheat to be treated on clean, hard barn floor, or in wagon box, or on canvas. The floor, wagon box, or canvas should be cleaned with a strong formalin solution, or with boiling water. Spread grain out a few inches deep.

(3) Sprinkle solution over grain with ordinary garden sprinkling can. Use about 1 gallon of solution to each bushel of grain.

(4) Shovel grain over and over. One person can handle the sprinkler while another thoroughly mixes the grain.

(5) Shovel treated grain into a pile and cover with canvas or gunny sacking that has previously been dipped in formalin solution or boiled in water. Leave covered for 2 or 3 hours.

(6) Spread grain out not more than 2 inches deep and allow to dry.

(7) Treated grain, if not planted directly, should be kept in smut-free sacks or bins. Disinfect sacks or bins with strong formalin solution or boiling water. Drills may be disinfected by washing out with strong formalin solution.

LOOSE SMUT.—The entire head of wheat is affected and turned into a powdery mass. It is earlier than bunt, and the smut-masses break open immediately after the head appears. At harvest time only bare stalks of diseased heads remain. The smut-mass has no odor. Smut-balls are not formed. Sometimes only a part of the grain-head is affected; in such cases it is always the lower part. Infection of sound seed always takes place before harvest time. Seed

that is apparently sound may carry the smut fungus within. Loose smut is carried over within the seed, not on the outside, as in the case of bunt.

Control.—The object of seed treatment is to kill the smut fungus that may be within apparently healthy grain, and at the same time not injure the germ. The formalin treatment is worthless. It is also needless to try and remove affected seed by placing seed wheat in cold water, or by fanning it. If you do not treat your own grain, be careful to get seed from a field that is smut-free. With considerable care, seed with loose smut of wheat may be treated successfully, by use of *hot water method*. This method is as follows:

(1) Soak grain for 5 or 6 hours in cold water. Use small quantities of grain (about 10 lbs.), placed in coarse sacks.

(2) Remove grain, in sacks, to tub or barrel No. 1, in which the temperature of the water is about 110 to 120 degrees F. Keep the grain in this 1 or 2 minutes. *Use good thermometer.*

(3) Remove grain to tub or barrel No. 2, in which the temperature of the water is kept *exactly* at 129 degrees F. Leave grain in this 10 minutes.

(4) Spread seed out to dry.

(5) In the above process some seed is killed. Hence it is necessary to increase the amount of seed used per acre. The extra amount of seed can be determined by comparing treated and untreated seeds when tested for germination.

OATS.

BLADE BLIGHT.—This is a bacterial disease which at first causes yellowing of the leaf. Diseased portions on the leaf are either round, or long and streak-like. The trouble usually begins at the tip of the leaf and works down into the plant. It may, however, start on the lower portion of the plant. In advanced cases the leaves collapse and take on a mottled reddish color. The leaves often crack and there appear droplets of a sticky fluid on their surface. At first this fluid is yellowish, but later it turns brown.

Control.—No control has been found.

LOOSE SMUT.—The common smut of oats is the loose smut. It appears as soon as the plant begins to head. As a rule, all heads on smutted plants and all grains on smutted heads are affected. Chaff as well as grain is smutted. Smut spores are early blown away by the wind, leaving the oat stem bare. Spores are carried over winter, clinging to the outside of healthy grains.

Control.—The formalin sprinkle as described under bunt of wheat is entirely satisfactory. It is unsafe to use bluestone (copper sulfate) in treating oats for smut.

CORN.

SMUT.—The appearance of corn smut is well-known. Black smut masses usually appear on the ears, but also frequently on tassels, leaves, and stems. Black spores are produced in tremendous numbers and scattered broadcast by the wind. Spores may live in the soil or in the manure pile. The spores that rest over the winter, in the spring produce spores of another type, and it is these new spring or early summer spores that infect the corn plant. Any part of the corn plant may be infected. Hence seed treatment is useless.

Control.—(1) The formalin sprinkle and hot water treatments are useless. Corn smut cannot be controlled by any form of seed treatment.

(2) Corn smut spores may pass through the digestive tract of animals without destroying their germinating power. Furthermore, the spores may actually grow and reproduce in fresh manure. Use well rotted manure, as it contains few or no living spores.

(3) Remove and burn all smut masses from field before they discharge the spores.

(4) Since spores may remain alive in the soil several years, crop rotation is of value. Any other crop than corn may be used in the rotation, for corn smut spores cannot cause smut, or be carried over, in any other plant.

SORGHUMS.

SMUTS.—Under the name sorghum are included milo, kafir, feterita, durra, kaoliang, broom corn, Sudan grass, and shallu. There are two smuts of the sorghum, kernel smut and head smut. In kernel smut of sorghum, each kernel becomes a smut mass, and the head retains its usual shape. The disease appears early in the season. The formalin sprinkle is an entirely efficient treatment for sorghum kernel smut. It is the more common sorghum smut.

In head smut of sorghum, the entire head becomes a large deformed smut mass. It is a loose smut. The life history of this smut is not well understood. Seed treatment is probably of no use. Cut out and burn infected plants. Rotation of crops may be of advantage. Milo is not attacked.

SUMMARY OF TREATMENTS OF CEREAL SMUTS.

1. Use the formalin sprinkle for:

- (a) Bunt or stinking smut of wheat.
- (b) Covered smut of barley.
- (c) All smuts of oats.
- (d) Kernel smut of sorghums.
- (e) Smuts of millets.

2. Use the hot water treatment for :
 - (a) Loose smut of wheat.
 - (b) Loose smut of barley.
3. Seed treatment is useless for :
 - (a) Corn smut.
 - (b) Head smut of sorghums.

CHERRY.

SHOT HOLE.—This disease is evidenced by leaf spots, which are brown, circular, and with margins that may or may not be sharp (Plate VI). Shot-holing may be caused by the diseased portion falling out. In severe cases large numbers of spots appear in a cluster causing the whole leaf to assume a yellow color and fall.



Plate VI. Shot-hole of plum.

This disease must not be confused with spray injury. Fruit and fruit stems are rarely attacked.

Control.—(1) Spray with self-boiled lime-sulfur, 8-8-50; atomic sulfur 5-50; commercial lime-sulfur $1\frac{1}{4}$ -50; or Bordeaux mixture, 4-5-50 formula.

(a) First when petals fall, beginning when they are three-fourths off.

(b) Ten days to two weeks later.

(c) Three to four weeks before fruit is harvested.

(d) In sections, subject to severe attacks, an application should be made just after the fruit is picked.

(2) If possible, dispose of fallen leaves by fall or spring plowing.

BLACK KNOT.—See Plum, page 37.

CROWN GALL.—See Apple, page 12.

CUCUMBER.

BACTERIAL WILT.—This is evidenced by a wilting of the leaves and runners. There is no indication of injury to the roots, such as blackening, or to the leaves and stems, such as spotting. The leaves even retain their green color for quite a time. The water tubes are plugged, thus causing a wilting. By squeezing an infected runner, there oozes a sticky, milky, stringy liquid. This wilt also occurs on the Hubbard squash and cantaloupes.

Control.—Practice crop rotation.

(2) Insects are important agents in the spread of the disease. Spray for squash bug and cucumber beetle.

(3) Remove and burn affected parts promptly.

DOWNY MILDEW.—This disease is found on almost all cultivated species of the gourd family, such as cucumbers, muskmelons, watermelons, squash, and pumpkins. Affected leaves have irregular yellow spots, which run together in serious attacks causing the entire leaf to yellow, shrivel, and die. A whitish downy mass tinged with purple can often be seen on the under side of the large older spots. In weather unfavorable to the disease, the spots remain small. The disease starts with older leaves, and spreads toward the ends of the vines. Hence the center of the hill is first killed. Very few cucumbers are produced on diseased vines.

Control.—(1) Spray with Bordeaux mixture, 4-5-50 formula.

(a) First application, when the vines begin to run.

(b) Later sprayings, at intervals of about ten days, if the weather is dry, and oftener if the disease spreads rapidly.

POWDERY MILDEW.—A common disease attacking all parts of the cucumber. This trouble has the general characteristics of all powdery mildews. At first the diseased stems are covered with whitish, powdery, circular spots. Later, these spots spread and may cover the entire leaf, which becomes distorted and retarded in its growth. Infection is found mostly on the upper surfaces, and on older leaves. Stems are similarly attacked. Blossoms attacked fail to set their fruit. Diseased fruits develop the same symptoms as leaves. Such fruits become distorted and bitter.

Control.—(1) Apply flowers of sulfur with a good dust sprayer. The sulfur must be distributed to every part of the plant. Vines should be sulfured 1 to 7 times.

- (a) First application, when the shoots are a foot long.
- (b) Second application, at the first sign of the mildew.
- (c) Later applications, as need indicates and according to the weather. Less sulfuring is necessary during hot, dry weather.

CURRENT.

CANKER OF CANES.—This disease has become prevalent in certain sections of the state. Apparently healthy canes may bear the fungus, which causes the trouble, for several years. The first indication of the disease is yellowing of the leaves and early coloring of the fruit. Positive evidence of the presence of the canker in a patch of currants is the appearance of pinkish, cushion-like masses on dead canes (Plate VII).

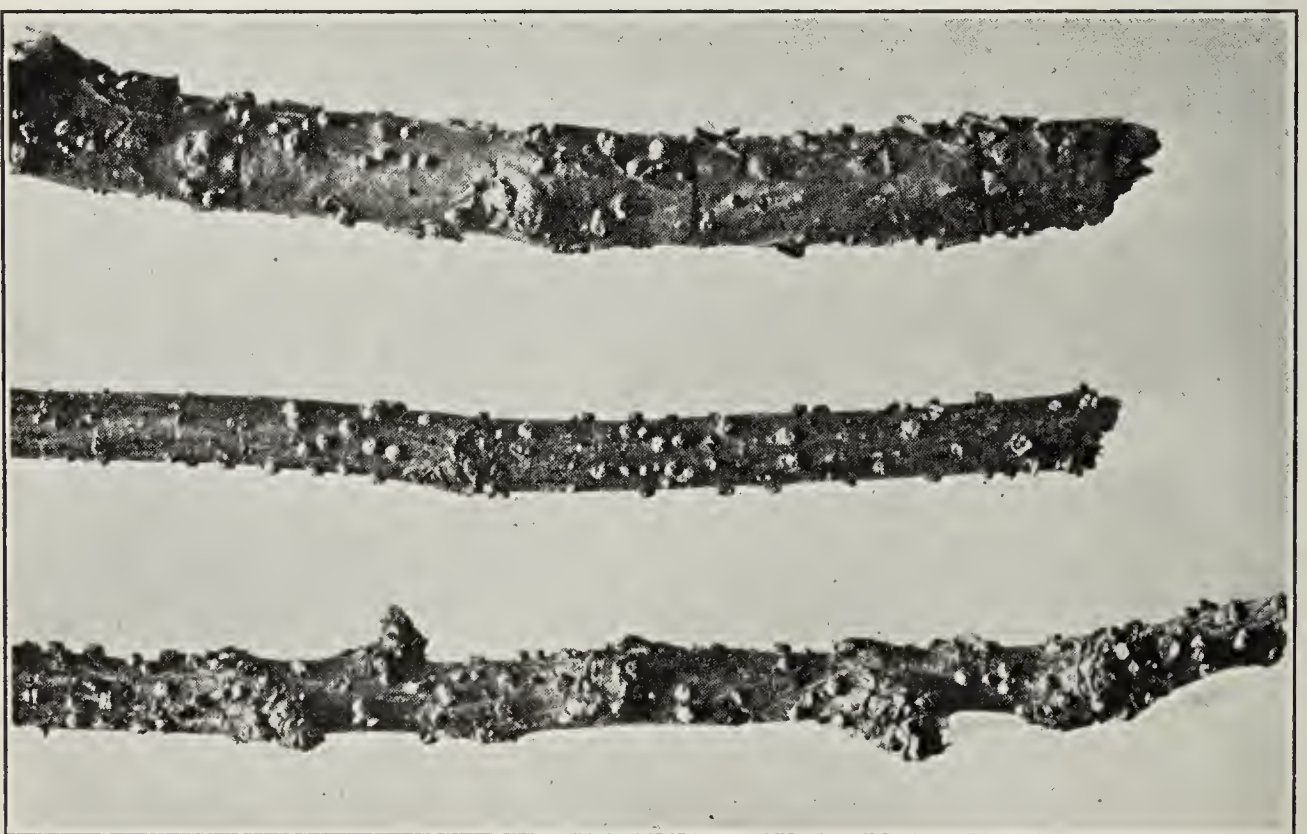


Plate VII. Canker of currant canes. The cushion-like bodies seen scattered over the canes are pinkish in color.

Control.—(1) Cut out and burn all diseased plants as soon as the trouble appears in the spring.

(2) All cuttings for planting should be made from stock that is known to be healthy. Do not even take cuttings from plants that appear healthy when such plants stand in a plantation known to have diseased plants.

(3) Spraying is not recommended.

CURRANT LEAF SPOT.—Diseased spots are about one-eighth of an inch in diameter and more or less angular. They have grayish centers with brown borders. Minute black specks may be seen on older diseased areas within the grayish center. Spots may be few or numerous. In the latter case, the leaf turns yellow and falls. Serious defoliation may result. This spot is easily distinguished from the anthracnose leaf spot by its larger size, its well-defined area, and its gray center, usually with black specks. Anthracnose leaf spots are black and small.

Control.—See anthracnose of currant.

ANTHRACNOSE.—This disease attacks fruit, fruit-stems, new canes, leaves and leaf stalks. Newly developed spots on the berries are rather noticeable. As the berries ripen, spotted fruits are less conspicuous. This is probably because the worst affected fruit has dropped. The spots on fruit are black, circular, and resemble fly specks. Affected berries do not rot or wither. Spots on the fruit-stems are black, and slightly sunken. They are from one-fourth to one-half of an inch in length and extend half way or more around the stem. Spots on new canes are rather inconspicuous. They are pale yellow or light brown, therefore almost the color of the cane. A slight discoloration of the bark is produced. The lower leaves are attacked first. They become thickly covered with small, dark brown spots. Affected leaves turn yellow and fall. Spots on the leaf-stalk are conspicuous. They are black and slightly sunken. Diseased plantations are easily recognized by the yellow color of the foliage. At ripening time the diseased leaves fall, leaving the vines bare, and exposing the red fruit.

Control.—(1) Spray with Bordeaux mixture, 4-5-50 formula, or lime-sulfur, 1 to 50.

(a) First application, made on bare canes before the leaves appear.

(b) Second application, made while the leaves are unfolding.

(c) Later applications, at intervals of from two to three weeks, until the fruit is two-thirds grown.

FLAX.

WILT.—The cause of flax wilt is a fungus which grows on the inside of the flax plant. It is found that the roots of diseased plants

are chiefly affected. Flax wilt may live over in the soil from year to year. Plants of all ages may be attacked. They wilt and die as from lack of water. The disease may spread very rapidly.

Control.—(1) Flax is being grown for the first time in many sections of the state. Since the spores of the fungus causing wilt may be carried by the seed, it is particularly important that clean seed be used, to prevent the introduction of the disease to the soil. Disinfect seed with formalin. This treatment is as follows:

- (a) Make solution of formalin at the rate of 1 pound to 40 gallons of water.
- (b) Spread seed upon a clean canvas or good tight floor.
- (c) Sprinkle a small quantity of solution upon the seed. At the same time, rake the seed about. Take pains that all seeds are moistened, but do not use so much of solution as to cause the seeds to stick together. There is danger from using too much moisture. Use about $\frac{1}{2}$ gallon of solution to each bushel of seed.
- (d) Allow the seed to stand for several hours, covered by a canvas, then rake and stir until thoroughly dry.
- (2) Fanning seed before treatment will remove many light weight infected seed.
- (3) Store flax seed in dry place. The fungus grows on moist seed.
- (4) The wilt fungus is held over in old flax straw and stubble. Hence remove and burn infected flax straw and refuse.
- (5) Do not use manure made from infected flax straw. Well composted manure will contain no spores capable of germination.
- (6) If wilt becomes bad, plant infected land to some other crop.
- (7) Use disease-resistant varieties.

GOOSEBERRY.

MILDEW.—English varieties of gooseberries suffer more from the attacks of this fungus than American sorts. The frost-like coating of the parasite appears on stems, leaves, and fruit. The whitish, cobwebby growth becomes darker in color later in the season, and careful examination with a hand lens will show the presence of numerous black specks over the entire diseased surface. The black bodies carry the spores.

Control.—(1) Spray with potassium sulphide, 1 oz. in 2 gallons of water. Apply first spray just when the buds begin to open. Follow this with sprayings at intervals of about 14 days until the fruit is ready to pick.

(2) Establish good circulation of air about the plants by cutting out the lower drooping branches.

LETTUCE.

LETTUCE DROP.—The first indication of the disease is a sickly plant. Later the outer leaves wilt, one after the other, and fall flat upon the ground. Finally, water-soaked areas are produced over the stem, and the whole plant falls over and rots away. Such plants show a cottony growth on the under side of affected leaves. In the last stages of the disease, many small black bodies may be formed upon the affected portions.

Control.—(1) Remove and burn all diseased plants as soon as they appear.

(2) Spray the place where the infected plants stood, either with Bordeaux mixture, 4-5-50 formula, or with bluestone dissolved in water at the rate of one pound to seven gallons of water, or with weak formalin.

(3) Guard against introduction of the trouble in refuse or compost which may contain diseased lettuce plants.

(4) Rotation. Do not follow lettuce with celery, or celery with lettuce, as both crops are subject to the disease.

(5) Set out healthy plants only.

(6) Soil steaming or sterilization is practicable for lettuce grown under glass.

ONION.

BLIGHT OR MILDEW.—In a few of the truck growing regions of the state, this disease has been rather serious. It makes its appearance the latter part of June or first part of July. Damp weather or excessive irrigation favors its development. It is possible to recognize the disease in its very young stages. Early in the morning, when there is moisture on the leaves, infected leaves have a peculiar, furry, violet tinge. Later on, they become covered with a white mildew-like growth, and finally collapse. As a result of the leaf infection, the onion bulbs do not reach their proper size.

Control.—(1) In case of serious outbreak of disease, spray with 4-5-50 Bordeaux mixture. Apply this from time to time until disease is checked.

(2) The disease is carried over the winter on dead onion leaves. Care should be taken to rake and burn all the tops.

(3) In case the disease has been serious for several successive years, it may be well to practice crop rotation, not going back to onions until three or more years.

PEA.

POWDERY MILDEW.—This disease is prevalent in the state on both garden and field peas. It is readily recognized by the white cobwebby growth on both surfaces of the leaves. Moist weather,

over-irrigation, and crowded condition of plants favor its development.

Control.—(1) Bordeaux mixture readily controls it. It is seldom a practical remedy, however, as the disease is not often severe enough to warrant the expense.

(2) Keep soil well-drained.

(3) Do not overcrowd the plants.

(4) Early crops are not as liable to attacks of fungus as late crops.

PEACH.

SCAB.—The disease is found on fruit, leaves, and twigs. It is also known as “black spot” and “freckles.” Spots on the fruit are about $\frac{1}{8}$ of an inch or less in diameter, dark brown to blackish, and nearly circular. Diseased areas are found only on the surface and may be slightly depressed when many spots come together. Frequently, individual spots crack. If a mass of spots come together, producing a “smutty” or blackish appearance, the peach cracks open and shrivels. Infection is most abundant about the stem attachment and weather side of fruit. On the leaf the spots are nearly circular and are formed only on the surface. They are pale green in early stages and a yellow-brown or purple in later stages. Wood of the current season may be attacked.

Control.—(1) The disease is very easily controlled by spraying. Spray with 8-8-50, self-boiled lime-sulfur, about one month after the petals drop and again three or four weeks later.

BLIGHT.—This disease occurs on fruit, leaves, and stem. The spots on fruit are irregularly oval to circular. At first, they are pink, but later become typically brown with a pink outer ring. These spots are slightly raised and found only on the surface. Gumming is not abundant on diseased fruit. Badly infected fruit is shed early. On leaves the spots are irregularly circular and reddish to brown in color. Spots may fall out, causing shot-holing. In severe attacks, defoliation may take place. On twigs the spots are irregularly oval in shape. At first they are reddish, but later become brown to black, and often sunken. Gumming is generally conspicuous on diseased twigs. Buds on the fruiting wood are killed.

Control.—Spray in the fall with Bordeaux mixture, 4-5-50 formula.

POWDERY MILDEW.—The leaves, twigs, and fruit are attacked. White irregular blotches are produced on the leaves, mostly along the midrib. In the shade, both leaf surfaces are affected. The leaves crinkle, curl, and in severe cases the younger ones near the tip fall. White blotches are formed on diseased twigs (Plate IX).



Plate VIII. Peach fruit attacked by powdery mildew.



Plate IX. Peach twigs attacked by powdery mildew.

The bark under these blotches becomes dry and brown. In severe cases the bark shrivels and the young tips often curve or are killed outright. Spots on fruit are at first musty or frost-like patches which later become almost pure white (Plate VIII). The skin under the spots becomes brown and the flesh becomes hard. The entire crop is often ruined for market.

Control.—(1) Plant trees far enough apart to allow free circulation of air. This tends to prevent development of mildew.

(2) Open head system of pruning is to be preferred.

(3) Spray with lime-sulfur solution, 1-50, with or without 3 pounds of iron sulfate added to 50 gallons of the mixture. Addition of iron sulphate increases covering and sticking qualities.

(4) Dusting with flowers of sulfur is also effective. This can be easily done with a dusting machine. The sulfur should be applied as early in the morning as possible while the dew is still on the foliage.

Applications for lime-sulfur or sulfur treatment:

(a) First application, made as soon as the disease appears and before it has become thoroughly established.

(b) Later applications, made at intervals of 9 days or often-er, according to the severity of the disease. One or two applications may be sufficient while in some seasons five or six applications are necessary.

PEAR.

FIRE BLIGHT.—Fire blight of the pear, apple, quince, apricot, and plum attacks blossoms, twigs, limbs or body, and fruit. The blight attracts special attention two or three weeks after the blossoming period. The fruit spurs at first shrivel, turn brown, and then black. Blight works down the twigs and branches into the trunk or body of the tree, often causing the destruction of the entire tree. The affected portion is somewhat sunken, dark in color, usually with a brownish tinge. In spring the diseased bark may be slightly blistered, and here and there drops of a clear, slimy liquid may collect. Later in the season, when the progress of the blight is checked, the infected bark shrinks, becomes smooth, and forms a definite line of division between diseased and healthy tissues. The trouble is seldom found on mature fruit. Hold-over canker on twigs is shown in Plate X.

The disease is caused by a bacterium which is spread chiefly by insects.

Control.—(1) Spraying the trees with a fungicide is not effective.

(2) A number of blight remedies have been placed on the market by manufacturers. They are supposed to make the trees im-

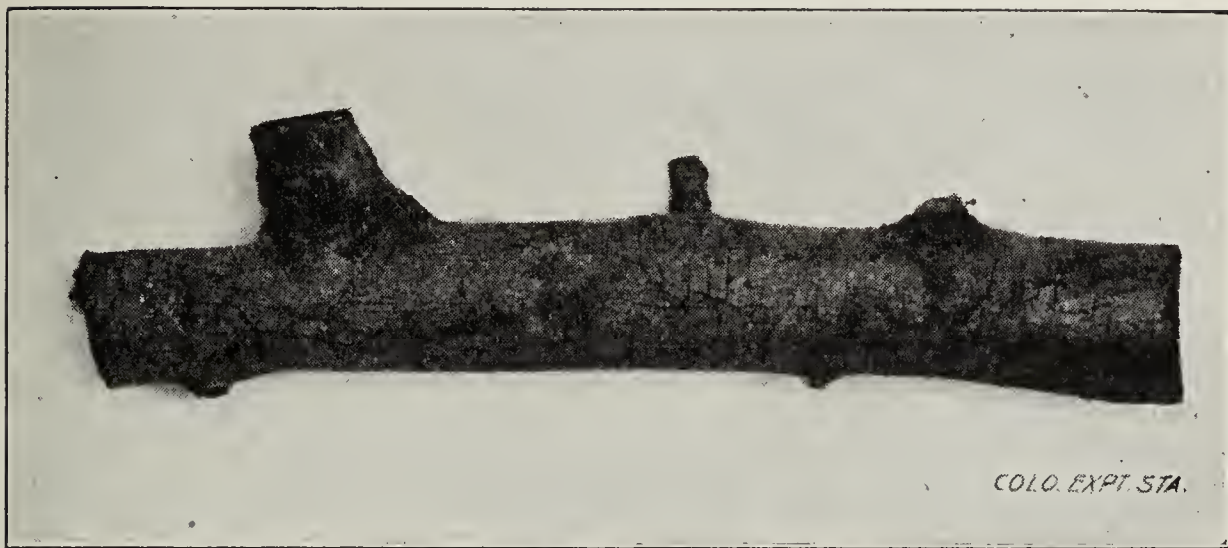


Plate X. Hold-over canker of pear twigs. Note the cracks from which the oozing takes place.

mune by the introduction of a fluid into the sap. These have not been proven successful.

(3) Strict sanitation and eradication methods are the most satisfactory means of control.

(a) All sources of infection should be destroyed. This can best be done by removing all diseased portions in the autumn after the leaves have fallen. Affected branches should be cut back from ten to fifteen inches below the discolored wood. Cankers in crotches should be scraped down to live wood, and disinfected.

(b) Trees should be inspected in early spring, and all cases of blight removed and burned. A weekly inspection of all trees during the growing season should be carried on as soon as the blossoms fall, and all cases of blight removed and burned.

(4) Tools as well as all cuts should be disinfected with corrosive sublimate, 1-1,000, so that bacteria are not spread.

(a) The corrosive sublimate may be carried in a bottle or wooden pail, and applied to the wounds and tools with a sponge.

(5) Collect diseased material in a sack; the sack may be strapped to the operator for convenience. Burn all affected material.

(6) A systematic and continuous fight in cutting and destroying diseased portions is essential for successful control.

(7) Disease is spread by insects. Hence keep these down by spraying with a good insecticide.

(8) The native thorn apples and mountain ash are a host for the organism causing fire-blight. Trees in the immediate neighborhood should be destroyed.

(9) Avoid heavy winter pruning, as it produces heavy succulent shoots subject to attacks of bacterium.

CROWN GALL.—See Apple, page 12.

RUST.—See Apple, page 13.

PLUM.

PLUM POCKETS.—The disease is present on fruit, twigs, and leaves. First evidence on the fruit is yellowing. The fruit then enlarges rapidly, attaining a size several times the normal. The surface becomes deeply wrinkled, and the pit fails to develop, having in its place a large air cavity (Plate XI., Fig. 2). The diseased



Plate XI. Fig. 1. Black knot on plum. Fig. 2. Plum pocket, showing the enlarged, darkened, diseased fruit.

fruit later turns brown, shrivels, and falls, or in some cases remains on the tree. Diseased twigs are enlarged, deformed, and usually somewhat curved. In later stages the twig turns brown. Infected leaves are abnormally thickened and deformed. Later they shrivel, become brown, usually remaining on the tree.

Control.—Affected branches and badly affected trees should be destroyed.

FIRE BLIGHT.—See Pear, page 34.

CROWN GALL.—See Apple, page 12.

SHOT HOLE.—See Cherry, page 26.

BLACK KNOT.—Early evidence of infection is indicated by a slight swelling of the branch. This is followed by a rapid increase in size. The knot attains its full size in 10 to 12 days. As growth increases, the bark ruptures and exposes a granular olive-green growth. Later this mass turns black (Plate XI, Fig. 1). Knots vary as to size and shape, some being only a quarter of an inch in length, while others attain a length of five or more inches. As a rule, they do not encircle the entire branch. Diseased twigs are often curved. The knots persist on old twigs and the next year they produce new knots. Old knots remain on trees for 5 or 6 years.

Control.—(1) All knots should be removed, by cutting at least 6 inches below the diseased portion, and destroyed.

(2) Spraying with Bordeaux mixture, 4-5-50 formula, just before the buds open, has been recommended.

POTATO.

EARLY BLIGHT.—This potato trouble is not prevalent in Colorado. The leaves become spotted in July or August, about the time the blossoms appear. The small brown spots are surrounded by concentric rings, which give them a very characteristic appearance. The spots may run together, causing withering and death of the entire leaf. As a result of the leaf affection, tubers do not develop normally. The tubers, however, are not diseased.

Control.—(1) Spray with Bordeaux mixture. This should be done at intervals of about two weeks. The first application is made before the appearance of the disease.

(2) Plant resistant strains.

(3) Maintain the vigor of the plant by proper methods of cultivation.

SCAB (OOSPORA).—This "Oospora scab," so prevalent in eastern states, has never been serious within the state. The most common scab on potatoes in Colorado is due to another fungus—*Rhizoctonia*. "Oospora scab" is a surface disease of the tubers. The fungus produces a roughened, pitted, scabby surface (Plate XII). It also occurs on beets, cabbage, and other plants.

Control.—(1) Use smooth, scab-free tubers for seed.

(2) Disinfect seed potatoes. Soak the tubers for two hours in formalin, 1 pound (pint) in 30 gallons of water.

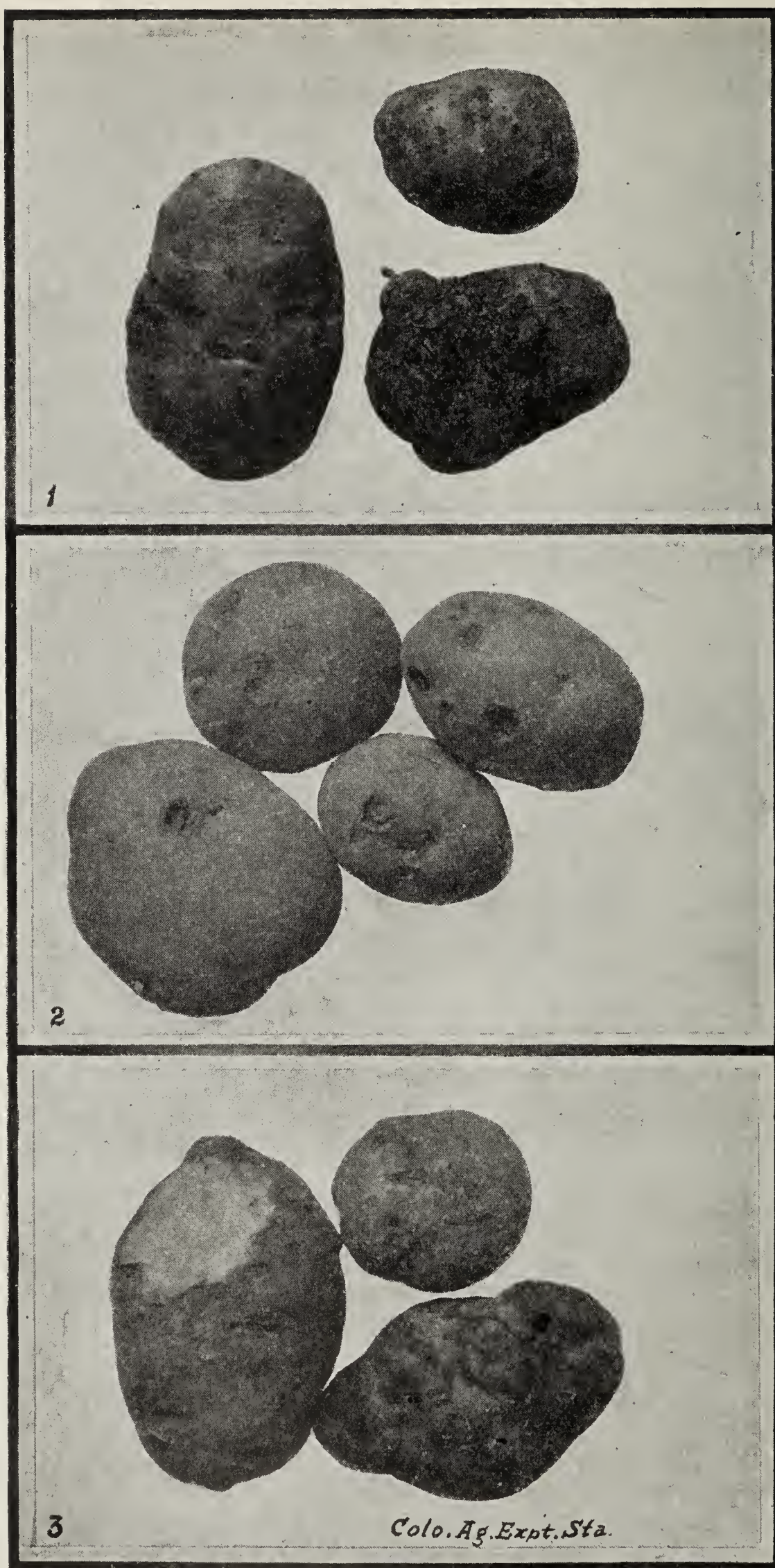


Plate XII. Scab of potatoes. Fig. 1. Surface scab. Fig. 2. Deep scab. Fig. 3. Scab produced by beetle.

(3) The spores of the fungus are uninjured in passing through the digestive tracts of livestock, and hence reach the field in the manure. Do not feed uncooked scabby potatoes to livestock.

(4) If the disease becomes prevalent in a soil, practice crop rotation, not returning to potatoes for 4 or 5 years.

FUSARIUM WILT OR BLIGHT.—The serious reverses that potato growing has undergone the last few years in Colorado have been ascribed to *Fusarium* wilt or blight. That it is the only cause of the epidemics is doubtful. However, it is quite certain that it is largely responsible.

In regard to the symptoms of *Fusarium* wilt, we quote from Professor B. O. Longyear, of this station:

"This trouble first manifests itself in the field by the wilting and yellowing of the lower leaves of plants that have reached the height of ten to twelve inches. In bad cases the entire foliage appears to suffer as though the plant were not getting sufficient moisture. Later on, the tips of the leaves turn brown and dry up, leading to the trouble commonly known as 'tip burn.' The edges of the leaves commonly roll inward during the heat of the day, although they may partially revive during the night.

"Badly affected plants will be found to have the root hairs and rootlets rotted away and often the larger roots appear sickly. Cross-sections of the main root often appear brownish in the region of the vascular bundles or woody part. Under the microscope thin sections of such roots and of the lower part of the stem will show the delicate filaments of the fungus which pass upward through the water-conducting tubes of the plant and eventually clog them to such an extent that the flow of sap is greatly obstructed. This is what causes the wilting and eventual drying of the foliage of the plant.

"The fungus also passes into the tuber-bearing stems under ground and frequently enters the stem end of the tuber for some distance. In bad cases the stem end of the tuber may be rotted away and the presence of the fungus deeper in is indicated by the browning of the vascular ring shown in a cross-section of the tuber. The fungus may also enter the tuber from the soil through any bruise, crack, or other break in the skin. Attacks of insect larvae upon the tubers are often followed by this disease through the wounds which the 'worms' produce.

"Under conditions of plenty of moisture and high temperature, this disease makes it most rapid progress and may reach its culmination at about the time when the tubers are ordinarily half to two-thirds grown. When a plant once shows the infection to any marked degree, all further growth ceases. The plants seem to stand still and eventually wilt down entirely or else struggle along in a dwarfed and sickly condition for some time.

"A common source of infection in newly planted fields is through the use of tubers for seed that already contain the fungus. Another

common source of the trouble is from planting the potato in fields that have previously shown the disease within two or three years. Such soils are said to be 'sick.'

"A second period of destruction due to this disease comes during storage. Tubers infected in the field when stored under conditions of



Plate XIII. "Little potatoes" and "aerial tubers," the former in a cluster beneath the soil surface, the latter on the stems above ground.

moderate temperature are apt to show a high percentage of dry rot. In such cases the fungus causes a blackening of the tuber, with a final outbreak of a whitish mold, and may serve to infect the wounds in other tubers."

Control.—(1) Spraying is entirely useless. The fungus is internal.

(2) Plant clean seed in a clean soil. The fungus is carried in the tubers and lives over in the soil.

(3) Practice crop rotation. This is the important lesson learned by Colorado potato growers. Fields in which *Fusarium* wilt has been bad, should not be planted to potatoes again until a lapse of 5 or 6 years.

RHIZOCTONIA.—This well-known potato disease in Colorado goes by a number of common names: Rosette, little potatoes, aerial potatoes, scurf, stem rot, collar rot, and black ring. The fungus causing the trouble lives in the soil. The symptoms produced by its attacks upon the plant vary. Apparently healthy plants may produce but a few tubers; the plant "goes to top." Again there may be an abundance of tubers, crowded just below the ground surface, but these are small, hence the name, "little potatoes" (Plate XIII). The fungus girdles the stem (Plate XIV), shutting off the movement of starch from leaves to tubers; as a result, small tubers may be formed on stems above ground (Plate XIII). In some instances there is a profuse branching of the plant, and a clustering of leaves at branch tips, which give the plant a bushy appearance. Again the leaves may be twisted and curled. Examination of diseased stems, taken just below the ground line, shows characteristic brown or black surface spots and patches of various shapes. Diseased tubers may be somewhat scabby. Close examination of such will often show the presence of very small black specks, resembling dirt. These black bodies represent a stage of the fungus which lives over winter (Plate XV).

Control.—(1) Use clean seed in a clean soil.

(2) Treat seed before planting with corrosive sublimate. Soak 1½ hours in solution, using 4 oz. of sublimate to 30 gallons of water. Keep solution in wooden barrel—it corrodes metal. Do not eat treated potatoes.

(3) Keep diseased plants and tubers out of stable manure.

(4) Practice crop rotation.

(5) The disease is less prevalent in light, well-drained soil, than in heavy, soggy soil.

INTERNAL BROWN SPOT.—In Colorado this disease affects the Early Ohio almost exclusively. It has not been found on potatoes grown in irrigated sections. It is recognized by the dry, brown

spots, irregularly scattered throughout the flesh. It is thought to be due neither to a fungus or bacterium. The cause is not known. It is not contagious. Control measures are not known.



Plate XIV. Young potato stems attacked by *Rhizoctonia*. Note the darkened diseased patches near the ground line.

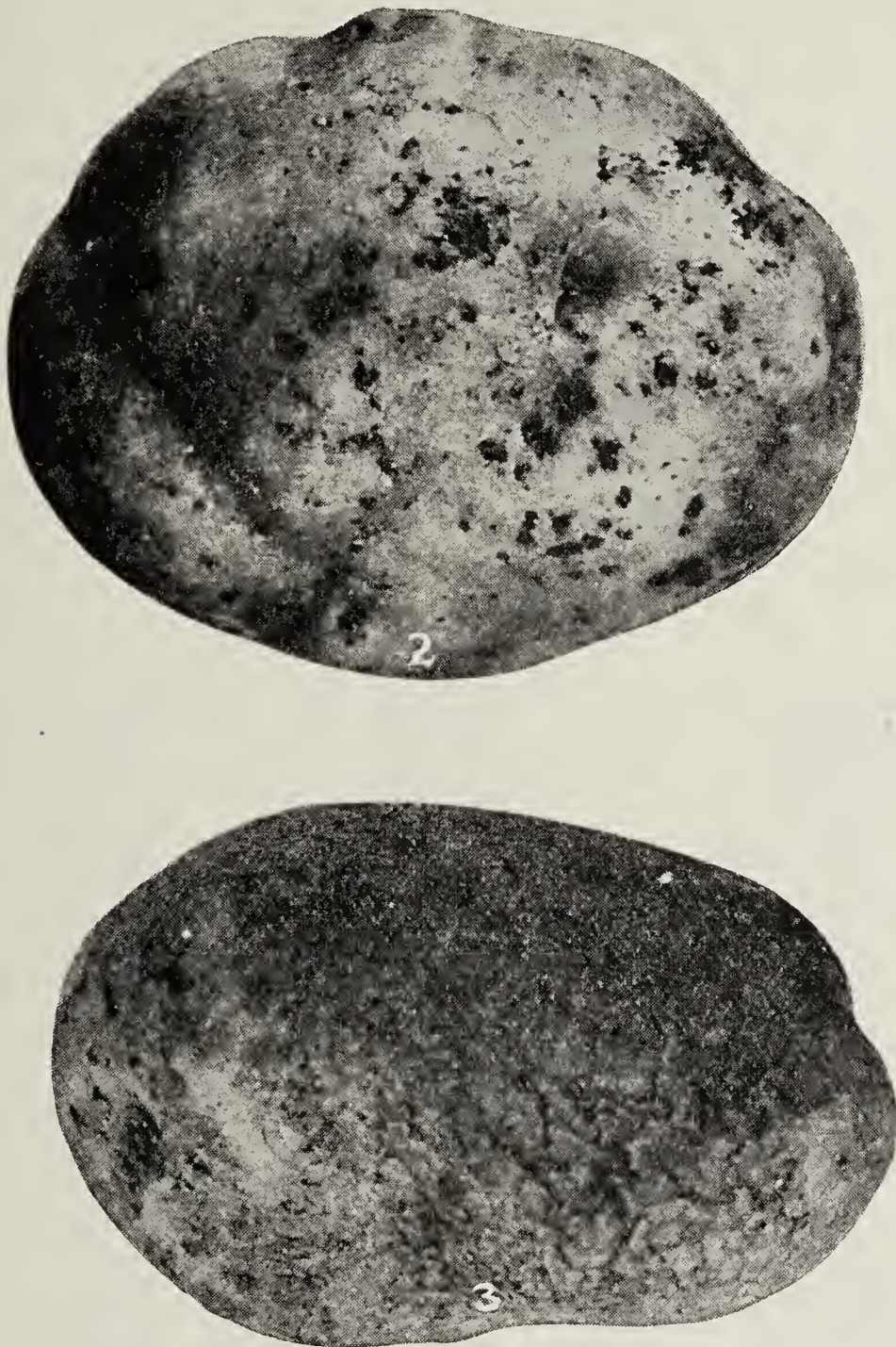


Plate XV. Fig. 2. Sclerotia of *Rhizoctonia* on seed potato. Fig. 3. The fine cracks seen on surface of potato are caused by the attacks of *Rhizoctonia*.

RADISH

WHITE RUST.—The white “rust” occurs not only on radish, but on other members of the mustard family, such as horseradish, turnip, and cabbage. It commonly affects leaves, but is also found on flower parts, distorting them to a marked degree. On the leaves the spore cushions are white and shining, and vary in size from mere specks to irregular patches an inch or more in diameter.

No serious injury has resulted from the attacks of this disease, as far as reports indicate.

RASPBERRY.

ANTHRACNOSE.—Young canes are chiefly attacked, although the disease may also appear on leaf and leaf-stalk. The spots on the canes are at first small and purplish, later they develop gray.

sunken centers bordered with purple. These spots enlarge, run together, forming irregular blotches which may encircle the canes. Badly diseased canes have roughened bark with a scabby appearance. In severe cases, the canes crack, wither, and die. Affected canes produce dwarfed leaves and premature, undersized fruit, which often dries. The first indication of the disease on the leaf-stalks is the production of minute spots. The fungus spreads from these spots into the leaf, where small affected areas are produced on the under surface. These diseased spots may drop out, causing shot-holing.

Control.—(1) Prune out and destroy all diseased canes.

(2) Rotation of crops. Avoid planting on site of diseased plantation.



Plate XVI. Spur blight of red raspberries. The twig on the right was sprayed.

(3) Set out only healthy plants.

(4) In severe cases spray young canes with Bordeaux mixture, 4-5-50 formula, with 2 pounds of resin-fish-oil soap added to act as a sticker.

(a) First application, when canes are uncovered.

(b) Second application, when new canes are 8 to 10 inches high.

(c) Later applications, one or two more sprayings thereafter at intervals of 10 to 14 years.

SPUR BLIGHT.—This disease (Plate XVI) is found on the young canes and leaf-stalks. On the lower half of young green canes chocolate-brown discolorations are produced chiefly at the leaf attachments. Later this discoloration spreads, causing some buds to dry, shrivel and die. Other buds are so weakened that the newly developed spurs die soon after starting. No fruit is developed on the lower half of diseased canes. In later stages the disease spreads and discolors the whole lower third of the cane a purple-brown. In this stage the bark often cracks, causing drying of canes. Such stems are brittle and easily broken. Infection on leaf-stalk at first is in the form of a small chocolate-brown spot. The fungus spreads from this spot into the cane. Infected leaf-stalks are weakened and later collapse, causing the leaf to droop and dry up.

Control.—(1) Spray with Bordeaux mixture, 3-2-50 formula, with 2 pounds of resin-fish-oil soap added to act as a sticker. This mixture should only be applied to the young canes and not to the fruiting canes.

(a) First application, last part of May or early June when canes are 8 to 12 inches high.

(b) Second application, two weeks later. Regulate somewhat according to the ripening period of the fruit so as not to discolor fruit.

(c) Third application, two weeks after the second.

(2) Remove and burn old fruiting canes as soon as the berries have been gathered.

ORANGE RUST.—This is a common disease attacking the leaves and canes. The under surface of infected leaves becomes covered with a mass of orange-red spores. The growth of leaves is retarded, and they become curled and distorted. Affected canes are weakened and stunted. They are non-productive and finally die. The fungus lives in the plant from year to year.

Control.—Pull up and burn all diseased plants.

STRAWBERRY.

LEAF SPOT OR LEAF BLIGHT.—Although this disease is of frequent occurrence in strawberry beds, it rarely becomes serious. It attacks the leaves principally and may be recognized by the characteristic white spots bordered by red or purple. At first the spots are purplish. The degree of susceptibility of a variety toward the disease varies with the locality.

Control.—(1) Remove and destroy all diseased leaves when setting new plants.

(2) The fungus winters over on the leaves. Hence, after the picking season, mow the bed and burn it over.

(3) Although seldom necessary, it will pay to spray in bad cases. Use Bordeaux mixture. Spray 2 or 3 times early in the season, and, if necessary, once later.

(4) Resistant varieties for a locality may usually be found.

BLACK ROOT.—Many plants have been sent to the Station affected with a disease, which we have called “black root.” There is a blackening and dying of the roots. As a rule, two-year-old plants are the worst affected, and the disease usually becomes evident in the spring. In a few cases, the trouble has appeared at the beginning of the winter season. No causal organism has as yet been associated with the disease. It seems to be most prevalent on soil that is poorly drained, or in bad physical condition, or on land that has been continuously cropped with strawberries without proper rotation with some legume. However, it has been noted in soil apparently in good condition.

TOMATO.

FUNGUS (*Fusarium*) BLIGHT.—In this disease the first indication is a yellowing of the lower leaves, followed by their wilting and dying. The trouble may progress slowly, or within a week the entire plant may be dead, depending upon weather conditions and the severity of the attack. In a section of a diseased stem, the woody portion is blackened. Very often the fruit remains attached to the plant and ripens earlier than usual. This is probably the same fungus that is responsible for a part, at least, of wilt in potatoes.

Control.—(1) Spraying is useless.

(2) Remove and burn infected plants. A single diseased plant may be the source of infection of a large crop.

(3) The disease may live in the soil from year to year. Practice a crop rotation system in which tomatoes and potatoes do not come oftener than once in four years.

(4) Spores of the fungus may be carried from field to field and even from farm to farm by soil or mud sticking to cultivating implements, horses' feet, or workmen's shoes.

FRUIT ROT—BLOSSOM END ROT.—This disease usually appears on half-grown to full-grown tomatoes. It starts in at the blossom end as a slightly sunken, dry spot, which enlarges, darkens, and becomes rotted. The blossom end rot of tomato is considered to be a non-infectious disease.

Control.—(1) The application of fungicides is not effective.

(2) The appearance and progress of disease are favored by dry soil conditions. Keep an abundant and regular supply of moisture in the soil.

SOME INJURIES NOT DUE TO FUNGI

SUN SCALD.—Sun scalding may be developed on the fruit or body of the tree, usually the latter. Cankers are produced on the body. The southwest side of the tree is most frequently injured. Young trees may be killed outright or much weakened. The sun's rays may injure the trees either directly or by reflection from the hot dry soil, or water in irrigation ditches that are placed near the tree. Cankers produced in this manner may easily be mistaken for fungous troubles.

Control.—(1) Newly planted trees should be headed low.

(2) Protect trunks of newly planted trees.

(a) By wrapping the trunks with burlap, paper, straw, wood veneer or wire netting.

(b) By shading the trunk with a board placed on the southwest side.

FROST INJURY (Plate XVII).—Late spring frosts often injure the developing fruit and leaves. Frosted fruits become russeted either at the blossom or stem end, or very often in bands about the middle. Injured fruits may be deformed. "Frost blisters" may be produced on the leaves. Such leaves are crinkled, or have blisters produced by a separation of upper and lower surfaces. The lower surface of injured leaves usually has numerous cracks. Cankers may be produced on the southwest exposure of the tree, due to a freezing of sap and consequent killing of tissue. Such cankers may be mistaken for fungous troubles.

SPRAY INJURY.—Both foliage and fruit may be affected. Injured fruits may be russeted or spotted. Leaf injury may be in the form of irregular, scattered, light brown spots, or the margin of the leaf may be browned, or in severe cases the entire leaf may be

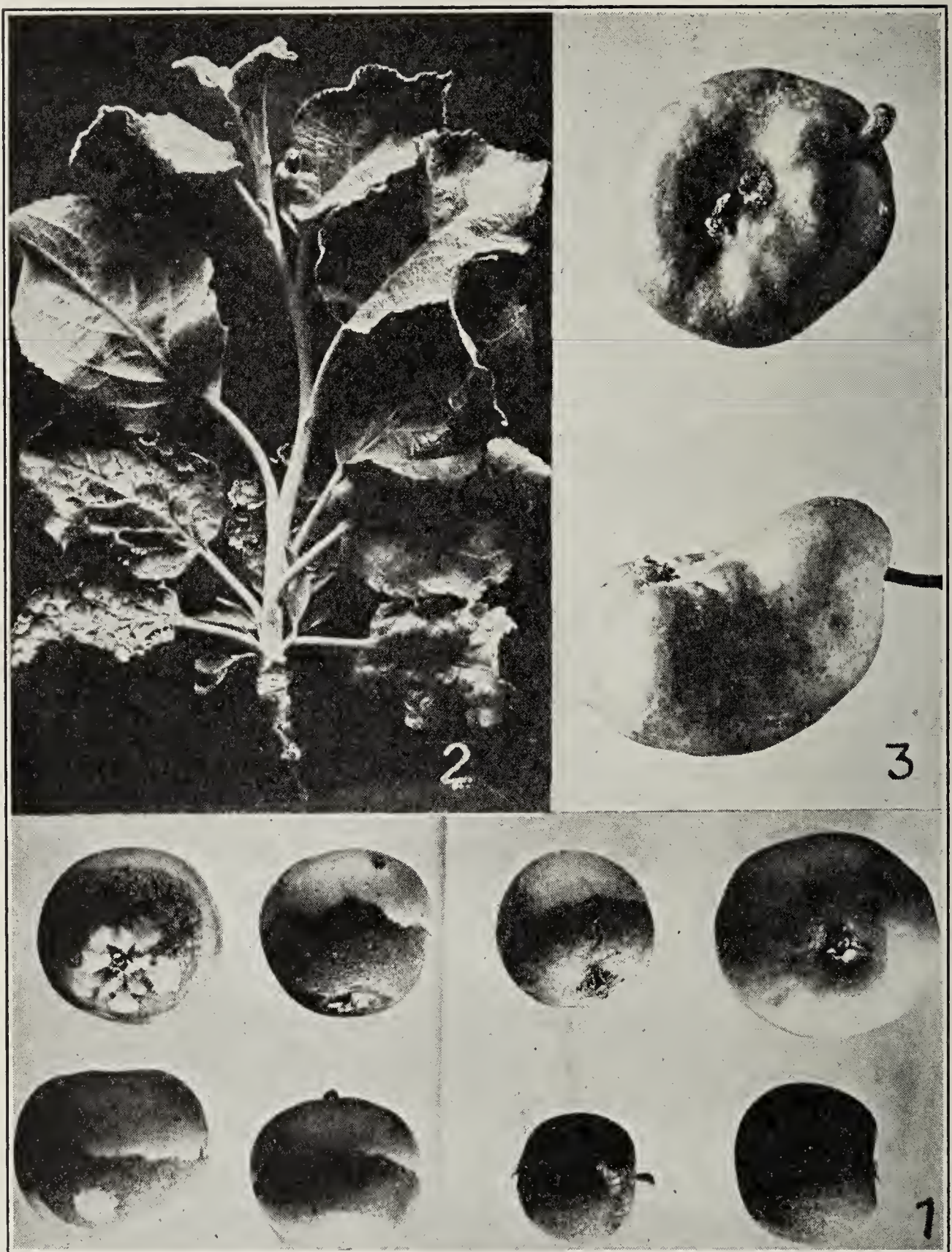


Plate XVII. Fig. 1. Frost injury on apples. Fig. 2. Leaves blistered by frost. Fig. 3. Pears deformed as a result of frost injury.

affected, turn yellow, and fall. In some instances the affected surface may slough off. The effect produced may sometimes resemble shot-hole of plum and cherry.

Control.—(1) Use pure chemicals.

(2) Apply spray as a fine mist, using high pressure and good nozzles.

(3) Apply spray in clear weather.

(4) Stir solution well before application.

(5) Follow carefully directions for making spray mixture. Do not get it too strong.

"NITER" INJURY (Plate XVIII.—The leaves of fruit trees af-



Plate XVIII. Apple leaf with "niter" injury. Note the characteristic browning along the margins.

ected by excessive quantities of niter in the soil have a characteristic appearance. The burning and shrivelling of the leaf begins at the tip, progresses rapidly along the margin, and finally involves the entire leaf. A few limbs, or the whole tree may be attacked. Of all our fruit trees, the apple seems to suffer the most.

ARSENICAL POISONING.—Headden ("Arsenical Poisoning of Fruit Trees," Bulletin 131 (1908) and Bulletin 157 (1910), Colo. Agri. Exp. Sta.), showed that many cases of death of orchard trees in Colorado were due to the action of the arsenic applied to trees

as a spray. A part of the arsenical spray, especially when used in excessive amounts, eventually reaches the base of the tree, and brings about injury to the crown of the tree.

Headden says, "This trouble begins, in by far the greater number of cases, at the crown of the tree and subsequently involves both trunk and roots. The first marked symptom is an early ripening of the foliage, usually followed by death about midsummer of the ensuing year. The crown of the tree is found to be girdled, the bark on portions of the trunk dead and sunken, and most of the roots dead, their bark destroyed and the woody tissue discolored, usually a light shade of brown, and sometimes exteriorly blackened."

Arsenical sprays constitute our most valuable insecticides and their use is not to be discouraged. But they should not be applied in excessive amounts. There is a tendency with some to give more applications than necessary.

"SEEPAGE."—Trees dying from too much water show symptoms markedly different from those affected with "niter." All the leaves of the tree may turn yellow. Discoloration of the leaf does not progress from the tip along the margins, as in "niter" leaves, but the leaf seems to be affected as a whole. Affected portions of "niter" leaves are brownish in color from the first, never yellowish. Trees killed by too much water never show girdling at the crown as do those killed by arsenic.

PREPARATION OF SPRAY MIXTURES AND DISINFECTANTS.

BORDEAUX MIXTURE.

Materials Used—

Copper sulfate (blue vitriol)	4 lbs.
Stone lime	5 lbs.
Water	50 gals.

This makes a 4-5-50 mixture of the spray. The amount of copper sulfate can be varied according to the formula given. The weight of stone lime should be equal to or exceed the weight of copper sulfate.

Apparatus—

- 2 half barrels with a capacity of about 30 gallons, made by sawing in two a 60-gallon barrel.
- 1 60-gallon mixing barrel.
- 2 or more wooden pails.
- 1 strong paddle, about 7 feet long.
- 1 pair hand scales.
- 1 strainer, of cloth or 20-mesh brass gauze.

*Preparation—**4-5-50 Formula From Fresh Material.*

1. Dissolve 4 pounds copper sulfate in hot water, place in half barrel and add water to make 25 gallons.
2. Slake 5 pounds of stone lime in the second half barrel and add water to make 25 gallons.
3. Mix solutions by having two operators, each provided with a bucket, dip up equal amounts of the copper sulfate and lime solutions, respectively, and pour them together at the same rate at a height of two or three feet above a mixing barrel (Plate XIX).



Plate XIX. Showing method of mixing copper sulfate and lime solutions in preparation of Bordeaux spray mixture.

4. Mix the whole thoroughly by stirring vigorously.
 5. Strain the mixture when putting into the spray tank.
 6. Apply to the plants with any good pressure spray pump.
- Use as soon as made.

If other than a 4-5-50 formula is given, take respective pounds as indicated in formula. For example, to make a 3-2-50 formula, take 3 pounds of copper sulfate and dissolve in 22 gallons of water, and 2 pounds of lime and slake and add to 23 gallons of water. Mix the two as before indicated.

Stock Solution.

Where spraying is to be done on a large scale, "stock solutions" of copper sulfate and lime are made up in advance.

1. Place 50 pounds of copper sulfate in a clean gunny sack and suspend it just beneath the surface in a barrel containing 50 gallons of water. This dissolves in 12 to 24 hours. One gallon of the solution contains 1 pound of copper sulfate.

2. Slake 50 pounds of good quality stone lime in a barrel and add water to make 50 gallons. When stirred, 1 gallon contains 1 pound of lime.

Preparation of 4-5-50 Formula From Stock Solutions.

1. Stir stock solution thoroughly.

2. Put 4 gallons of stock solution of copper sulfate in one of the half barrels and add water to make 25 gallons.

3. Put 5 gallons of stock solution of lime in the other half barrel, and add water to make 25 gallons.

4. Mix, following directions as given in preparation of 4-5-50 formula from fresh solutions, under 3, 4, 5, and 6.

5. After removing enough of the stock solutions for one spraying, mark on the barrels by nailing strips of boards just at the top of the solutions. Before the next spraying, add water to bring the solution up to these marks. This replaces the water lost by evaporation and gives a solution of known strength.

If other than a 4-5-50 formula is given, take respective gallons as indicated in formula. For example, to make a 3-2-50 formula, take 3 gallons of stock solution of copper sulfate and put into 22 gallons of water, and 2 gallons of stock solution of lime and put into 23 gallons of water. Mix the two as before indicated.

Preparation of Bordeaux Mixture With Addition of Resin-Fish-Oil Soap.

1. Dissolve 2 pounds of resin-fish-oil soap in 2 gallons of water.

2. Add only enough water to the slaked lime, before mixing, to make 23 gallons.

3. After the copper sulfate and lime solutions have been mixed, add the 2 gallons of soap solution.

4. Mix, strain, and spray as before indicated.

COMMERCIAL LIME-SULFUR SPRAY.

Buy the commercial product from some reliable dealer and use as directed.

*SELF-BOILED LIME-SULFUR SPRAY 8-8-50 FORMULA.**Materials—*

Stone lime	32 lbs.
Flowers of sulfur	32 lbs.
Water to make	200 gals.

In this preparation 4 times the 8-8-50 formula is used because it has been found that these quantities give more satisfaction and convenient conditions for cooking than when smaller or greater amounts are used.

Apparatus—

- 1 strong 50-gallon barrel.
- 1 strong paddle, about 7 feet long.
- 1 sifter (flour sifter).
- 2 or more buckets.
- 1 pair hand scales.
- 1 strainer, of cloth or 20-mesh brass gauze.

Preparation—

1. Weigh out 32 pounds each of lime and sulfur, having first sifted the sulfur.
2. Place lime in barrel and add about 4 gallons of water.
3. Add sulfur as soon as the lime begins to slake vigorously.
4. Stir preparation vigorously with the paddle, adding enough water from time to time to avoid "burning," and still not enough to "drown" the lime.
5. Add at least 25 gallons of cold water with vigorous stirring as soon as the lumps of lime are thoroughly slaked. It is very necessary to cool the preparation at this time by adding the water as indicated.
6. Make up to 200 gallons, or dilute fractions of the stock solution correspondingly.
7. Strain before putting into spray tank by running the solution through a cloth strainer or a 20-mesh brass wire strainer. Work through any lumps of sulfur with a small paddle.
8. Apply the spray with any good pressure spray pump.

AMMONIACAL COPPER CARBONATE.

Copper carbonate	5 oz.
Ammonia	3 pints
Water	45 gals.

Preparation—

1. Add water to the carbonate to make a thin paste.
2. Dissolve the carbonate in ammonia, diluted with about 2 gallons of water.
3. Make up to 45 gallons.

FORMALIN.

Non-poisonous to animals.

Formaldehyde (40 %), also called Formalin	1 pint
Water	40 gals.

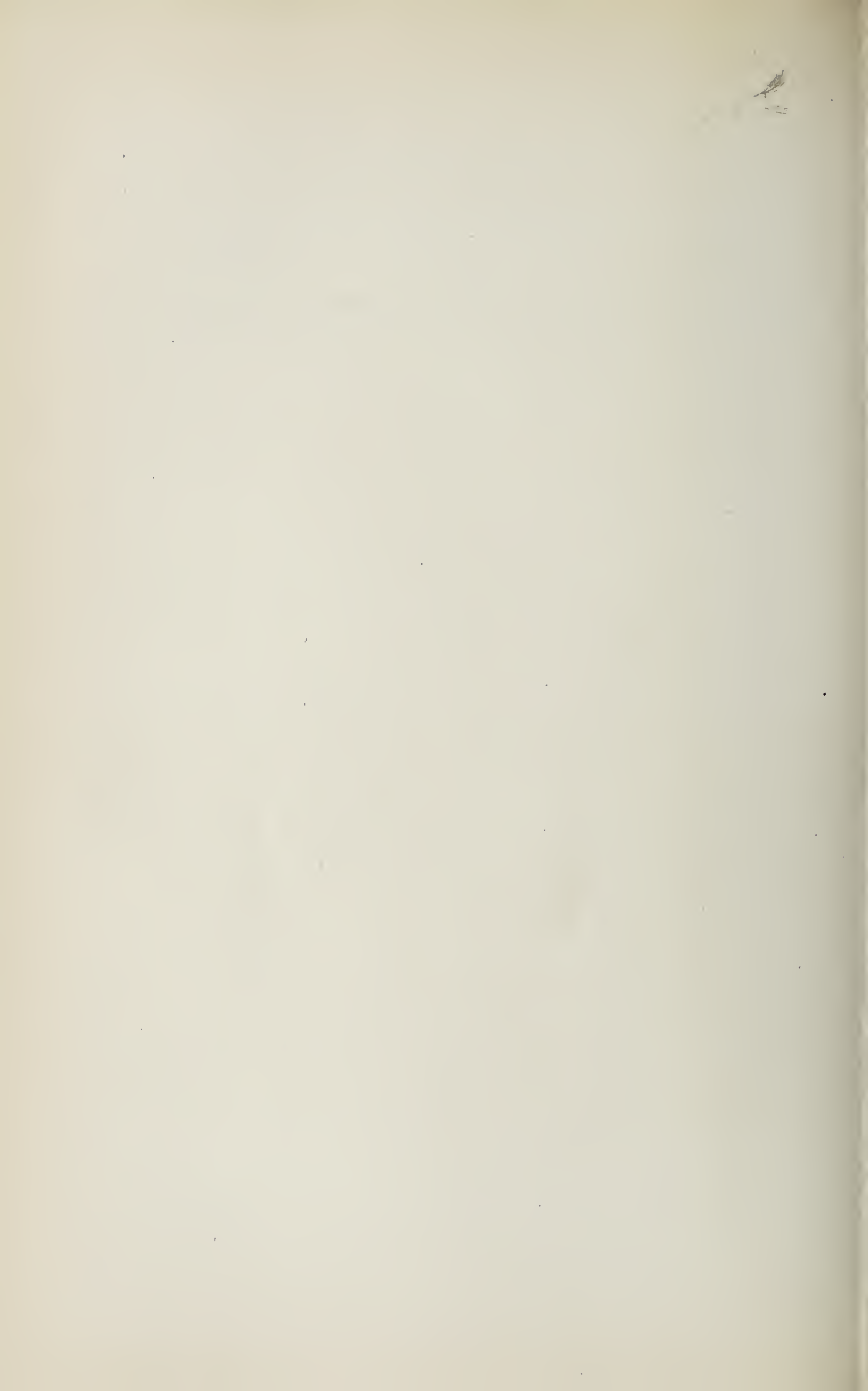
The above is the usual formula for formalin. The amount of water used varies with the use to which solution is put and with length of treatment. Use as directed in special cases.

CORROSIVE SUBLIMATE.

Deadly poisonous to animals.

Corrosive sublimate crystals.....	4 oz.
Water	30 gals.

Dissolve the corrosive sublimate in 2 or 4 quarts of hot water, and dilute this strong solution with water to make 30 gallons.



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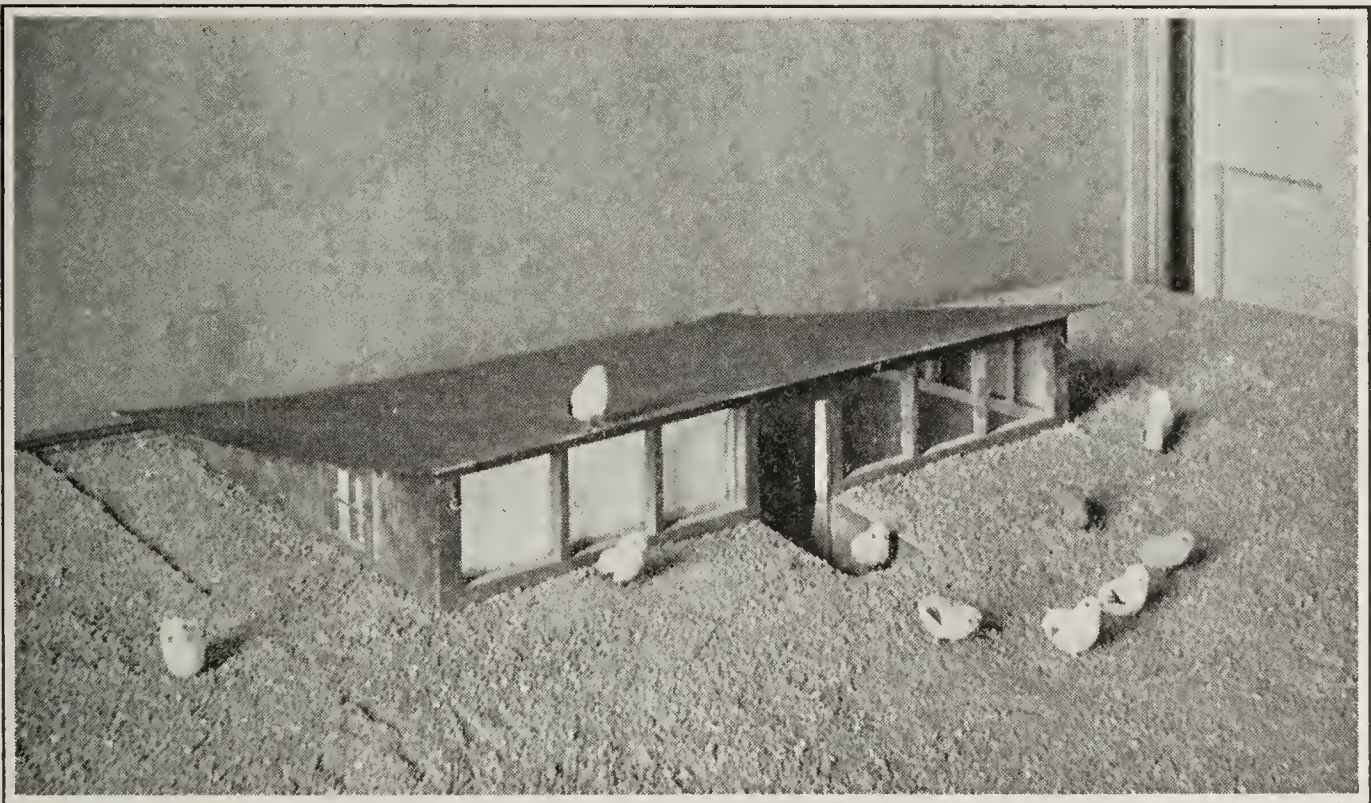
OF THE

Colorado Agricultural College

POULTRY RAISING IN COLORADO

—BY—

W. E. VAPLON



Under Ground Poultry House

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The Agricultural Experiment Station

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POULTRY RAISING IN COLORADO

This is not a technical bulletin; it does not give the results of investigations or experiments; its only excuse for being published is the fact that more inquiries are being received by the State Agricultural College and Experiment Station relative to poultry conditions and the care of poultry in Colorado than can be satisfactorily answered by letters.

Two poultry bulletins have been published by this Station: in 1910 bulletin No. 164, "Poultry Raising," and in 1912 bulletin No. 185, "Some Poultry Diseases." Both editions are exhausted and the demand for practical information is steadily increasing.

Only such matters have been taken up as are of interest to the person wishing to make poultry raising a business, whether in large or small degree, and the basis of the work is the questions received by the College and Station. Each subject has been discussed as though in direct answer to such questions.

Colorado needs more hens than she now has to supply home demands. Turkeys raised in Colorado are considered the equal of those raised in Minnesota and Iowa, which states have long been noted for turkey quality, and they are in demand at profitable prices in the big eastern markets..

Good prices for eggs and poultry of all kinds must prevail in the West, probably for all time, and there is no reason why scientific business principles applied to poultry raising will not net as good returns as when applied to any other line of agriculture.

COLORADO FURNISHES FAVORABLE CLIMATIC CONDITIONS

Some sections of our country have milder winters, some have longer summers, but we doubt if any offer more favorable climatic conditions than Colorado, and certainly few offer as many. Sunshine is the rule even in cold weather. The low precipitation makes it possible for poultry to spend much of the time out of doors, and we need have no damp buildings. Cool nights after warm summer days, and dry, sunny autumns, promote vigor and quick maturity. Spring sometimes encroaches on summer, but early chicks thrive under cover if properly cared for.

GOOD MARKETS

Of the entire population of Colorado, about one-fourth live in Denver and one-fourth in the mining and mountain districts of the State; only about four-tenths live in rural communities or districts. More than 200,000 tourists visit Colorado during the year and many of these make this state their summer home. These conditions make it necessary for Colorado to import approximately two and one-half million dollars of poultry products a year, besides sending out many thousands of dollars for breeding stock. Even did we produce more than enough to supply home consumption, to the north, south and west are states importing vast quantities of poultry products, that would become valuable customers for our surplus.

CHARACTER AND VARIETY OF CROPS

The statement is frequently made that grain is high in price in Colorado. This is true only where feed is bought at retail from month to month. Wheat, our staple poultry feed can be purchased at threshing time at \$1.10 to \$1.30 per hundred pounds. Much of the corn used for feeding purposes is shipped into the State, but can be bought at the same average price in the fall, and barley and oats will average the same.

There is not a grain or product needed for poultry feed that cannot be economically produced in any section of Colorado where commercial poultry raising can be profitably carried on. Corn is imported in large quantities because of the enormous sheep and cattle feeding interests.

HATCHING AT HIGH ALTITUDES

This Station has shipped eggs to all parts of the state. One setting of 15 eggs went to Parshall, Colorado, altitude 7,600 feet, from which 12 chicks were hatched. These eggs were carried in a commercial carton, not in a shipping case. During two days they traveled 360 miles by rail and street car, including a trip over the Continental Divide, then 14 miles in a wagon over rough mountain roads. We have had a report of 39 chicks from 45 eggs under hens at 8,500 feet, so that altitude is not the obstacle to good hatches it is so commonly considered to be.

LOCATION

The price of land, the market, and prices of feed are the chief factors to consider in choosing a location. Railroad facilities are excellent and one should be near a railroad if he is doing a wholesale business, as shipments should be frequent and time is money. If delivering products to the consumer, one should be near his trade. This means higher prices for land which may offset the higher prices received for the products.

AMOUNT OF LAND REQUIRED

Do not crowd, better go farther, pay less per acre and buy more acres. Crowding is the father of many evils and has driven many out of the poultry business. Rotation is as necessary in this line of agriculture as in any other. Fowls should never be allowed to run over the same ground indefinitely, but the soil should be turned over and cropped as often as possible. Fences are an abomination and the fewer the yards the better, but where yards are necessary, they should be large enough to permit a horse and plow to enter. The labor problem, like a ruler's crown, causes much uneasiness, can easily be made to blot out the profits, and horse labor is both cheaper and better than man labor where it can be used. Land of a rolling nature can often be bought at a lower price because of the difficulty of cultivation or the character of the soil. These conditions may be an advantage to the poultryman, especially if the land is porous enough to dry off quickly after a rain and still is suitable for producing good crops of

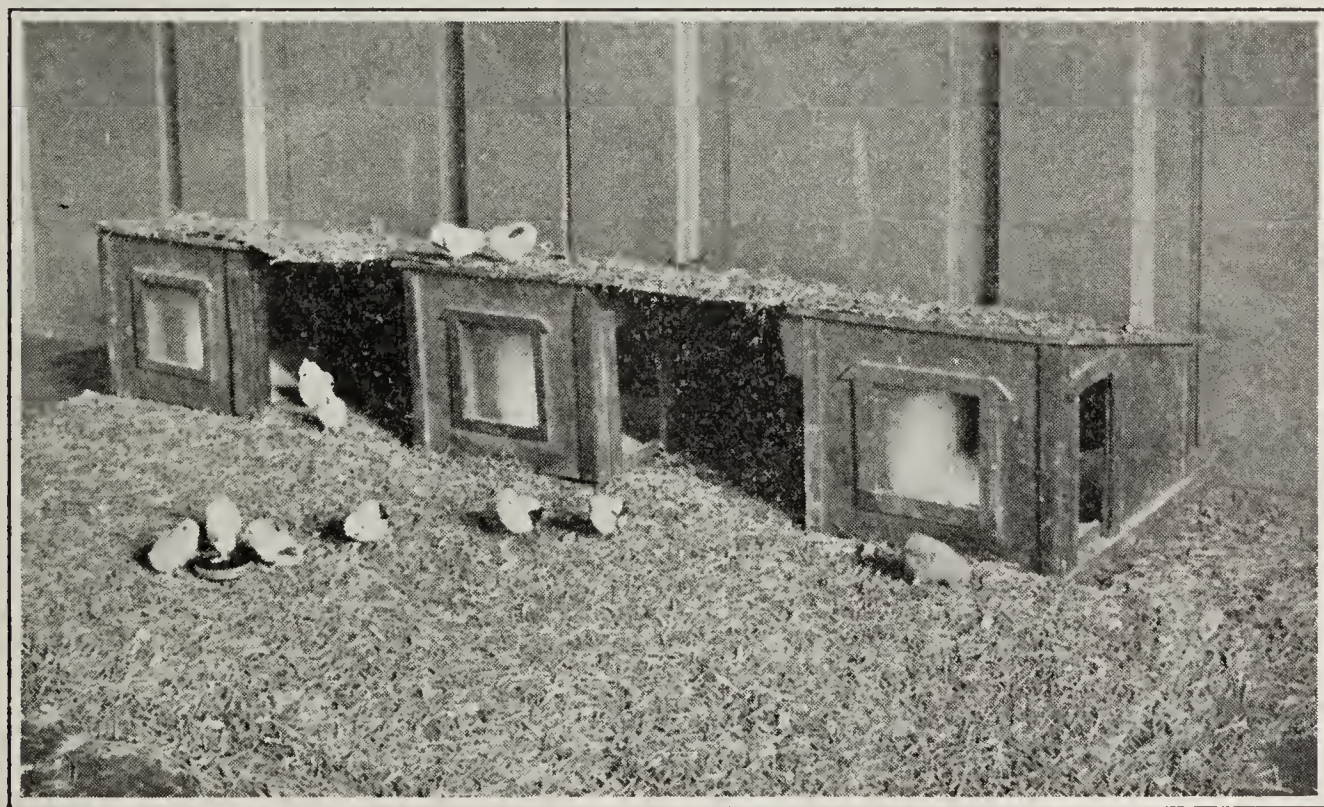
vegetables, alfalfa, grain, berries or other crop desired, these crops to be used for the poultry, or as added sources of income. This character of soil can be kept cultivated with less labor than heavy clay soil, thus insuring clean, pure range for the fowls. Especially if the land is level or low, it should be loose and porous, as heavy soil, when frequently wet, becomes foul and packed.

CONVENIENT ARRANGEMENT

In the matter of putting up buildings, fences, etc., convenience should never be lost sight of. The relation of each building to all the others, to the roads and highways, and to the residence, should be very carefully considered. Convenience means a saving of time and labor, which means added profits. The usual way of building each new poultry house in the most convenient place left vacant, without reference to those that may follow, will mean many unnecessary steps, discomfort and dissatisfaction. Plans should be made with an eye to the future, and then all building should be done in accordance with these plans.

BUILDINGS

The object of the house is to provide shelter for the fowls, and should therefore be wind and rain proof; a single thickness of drop-siding is sufficient in our climate. Where lumber is used, the best is cheapest; good sheating, covered or battened, will cost as much or more than drop-siding and will never make as tight a wall. Shiplap is not satisfactory as it soon dries out and leaves cracks. Whatever the materials used, they should be good. If economy must be practiced, it should be done in the size of the building rather than in the quality of the material.



Colony Straw House

The poultry house should face south; the front may be partly covered with burlap or muslin during cold nights, but should be open during the day. The burlap curtain will furnish plenty of fresh air when closed, providing all the necessary ventilation. The door should be either in the east or south, and the west and north walls and roof should be absolutely tight. We know of quite a number of poultry houses in Colorado facing east or west, but know of no good reason for it and many against it. There is no stronger ally in fighting disease and discomfort than the sunshine, and the south front, especially in the long house, permits the greatest amount of it to enter.

Colony, or individual houses, are becoming more popular each year. The long house, shown on previous page, furnishes ideal conditions for winter weather, and is made by placing cheap colony houses side by side about eight feet apart, and covering with straw. The north wall is made by stuffing straw between two lengths of field fencing in the form of two fences about a foot apart. Field fencing is laid across the roofs of the colony houses to support the straw. In the spring, the houses are moved into the fields and the ground on which they stood all winter is plowed up and cropped.

The house shown on this page is 7 ft. long, 9 ft. wide, or deep; it is used as a brooder house until chicks are large enough to be turned out



Brooder House

on range, when the brooder is removed and roosts are installed. The window in the rear adds to the comfort of the little chicks and tends to keep them near the heat, the brooder being placed at the north end. Much objection is found to the habit of hens facing the light in scratching for their food and piling the litter under the droppings platform.

This can be prevented by placing a small window sash in the rear wall under the platform.

A good house for a farm flock is built the same shape as this brooder house, 20 feet square, 8 feet high at the peak, 4 feet high front and rear. This house should have a full window in the west end and also one in the east end beside the door. These windows provide plenty of light and sunshine; the front being low can be left open except in zero weather, when a cloth curtain is sufficient protection. The hens are far enough from the opening not to be affected by draught, yet fresh air is always abundant. The front and rear are low, only 4 feet high, lessening cost of material and adding to the comfort in cold weather. Sunshine from three sides helps to make it a cheerful house.

When careful attention is given to cleanliness and to providing plenty of litter, more hens can be comfortably housed in a certain space than when conditions are not so favorable. A poultry house should always be roomy enough to provide comfort and scratching space in bad weather. Wet, cold feet will not help fill the egg basket.

Comfort and Convenience.—A hen would probably consider a house about 3 feet high ideal, especially in cold weather, but for the convenience of the caretaker we build them higher; unnecessary height means a colder and more expensive house, so the building should be as low as possible, consistent with convenience. The farther the roosts are from the open end the better for the fowls—twelve feet is better than less, fourteen or sixteen feet even better. The house should be shorter rather than narrower, if a certain amount of floor space is required.

The underground poultry house shown on outside front cover is slowly but surely gaining friends, especially in the plains regions. The chief and about the only cost is the roof. A cement plaster on the dirt walls is advisable, but is not necessary where the soil is firm. Dirt floor is good enough and can be renewed once a year. If the purpose of a poultry house is to provide shelter and comfort, the underground house fills the bill. A pit 4 feet deep, about 30 feet long and 14 feet wide for 100 hens; the roof either double pitch or shed style; if the latter, the north end resting on timber or concrete foundation 6 inches high, the south end raised 3 feet above the surface. The entire front, 3 feet by 30 feet, covered during cold weather with a burlap canvas curtain both for protection and ventilation. No windows are necessary on the south, as this curtain can be raised during the day, affording light and admitting the sunshine. If the door be made on the south, a small window can be placed in each end, giving more light and sunshine, also giving better ventilation in warm weather. Instead of steps there should be an incline; to avoid slipping cleats may be nailed to the incline, leaving a smooth space for the wheelbarrow.

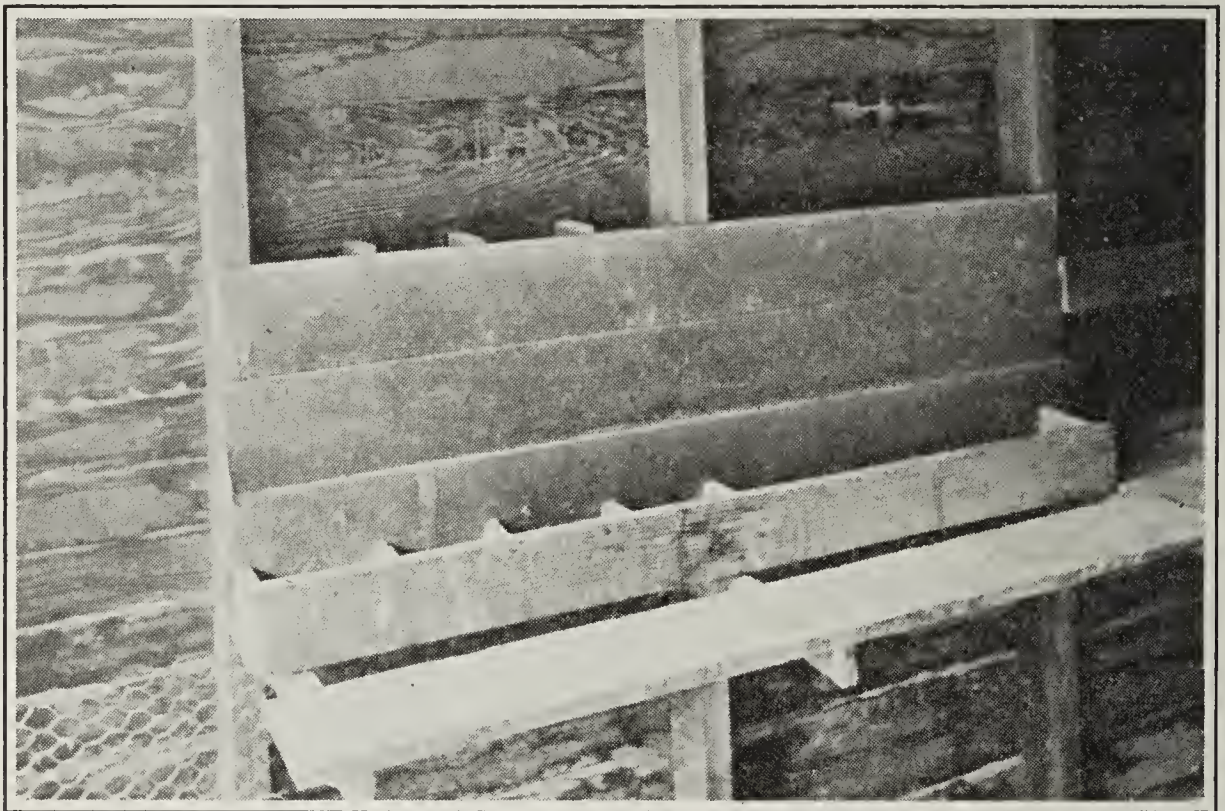
AVOID EXTRAVAGANCE

Cost of Building.—It is easy to be extravagant in building. Don't do it. Extravagance and waste are the causes of as many failures as inexperience. Limit the cost of providing house room to sixty dollars for material per hundred hens. It can be done for less, perhaps, but

ought not to cost more. A poultryman should be able to do his own building, even if he hires it done. By knowing how, it will be done right and to hire a carpenter for every little job is costly.

Nests.—Nests placed on the ground outside and against the building, covered with a slanting board to shed the rain, are sometimes very satisfactory; make openings through the wall of the house into the nests. If within the building, they should be above the floor and orange boxes will be found to answer the purpose. They are preferable to expensive lumber nests as they can be destroyed when mites infest them. When trap nests are used, one nest should be provided for each two or three hens, otherwise half the number of nests will be sufficient.

Fixtures.—All fixtures, such as grit boxes, feed hoppers, water dishes, etc., should be placed above the floor. The hopper shown on this page is built between the 2x4 studding and is roomy, convenient, clean, and can be made with box material.



Feed Hopper

Roosts.—Many use 2x4 material for roosts; a piece 2x2 is better and costs half as much. A round pole is objectionable, as it soon splits and the cracks offer a lodging place for mites. Instead of using hinges to fasten the roosts to the wall; a nail will answer the purpose if run through the piece supporting the roosts into the studding. The roosts may then be swung up out of the way when cleaning. They should be about ten inches above the platform, which is easier cleaned if covered with litter from the floor.

Water Supply.—No other water system can equal a living stream or spring, and if the fowls can help themselves at will, so much the better for them and for their keepers also. Every device or convenience that lessens labor, especially if it costs little or nothing, means so

much more profit, and carrying water to a large number of fowls is certainly very expensive by reason of the time and labor consumed. Where water is furnished, cleanliness should be carefully observed. Galvanized iron or stoneware drinking vessels are preferable. Wooden troughs are objectionable because they furnish lodgment for disease germs. Concrete troughs cost very little if made at home and are sanitary and enduring.

INCUBATION

It is our opinion that incubators are doing a better work, are more successful, than we think. Most people expect too much from a machine. They read in incubator catalogs only about the big hatches, never about the failures. Poultry papers tell the big stories, the man who fails seldom writes for the press. In comparing incubator hatches with those made by hens, we forget the hens' failures, do not even have the average in mind, and of course are disappointed at anything less than a 90% hatch.

There is no way of knowing, but we believe that not half the eggs entrusted to the hens produce strong chicks and that not half of the chicks hatched live to marketing size. If these figures are at all near the truth, a 50% incubator hatch would be gratifying. If we were to call for testimonials, hundreds could respond with reports of 50% to 80% hatches thruout the season. The cause of poor hatches in the incubator, especially if the hens are doing good work with the same eggs, is probably mismanagement, possibly poor construction of the machine. If more attention were given the breeding stock, more and stronger chicks would result. Immature breeding stock, forcing for eggs out of season, overfat old stock and lack of range or exercise are causes of much disappointment in hatching chicks. It pays to follow the instructions received with the machine until thoroughly convinced that some other way is better. Manufacturers have experimented much to make their machines do satisfactory work and can often help out when hatches are poor.

THE BEST BREED

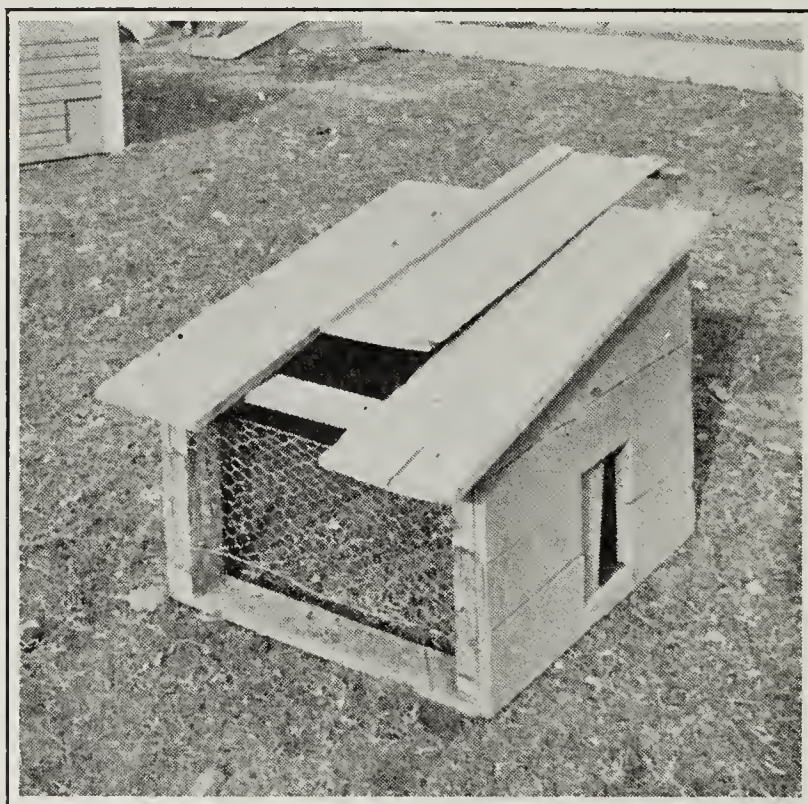
Farmers' Bulletin No. 51 of the U. S. Department of Agriculture gives a description and history of the various breeds of poultry. The Reliable Poultry Publishing Company, Quincy, Ill., publishes some very good booklets on various breeds.

Regardless of sentiment or personal preference, one should consider market requirements, whether egg or flesh production, or both, is intended. The family trade may and often does want a different fowl than does the commission merchant or hotel. The wholesale trade of Denver wants a large carcass, five pounds or over. The average family prefers a smaller fowl, especially at present prices. The preference for yellow skinned fowls is not so marked as formerly, as milk feeding is very generally practiced and this method of fattening produces rather a white carcass. Uniformity is appreciated; pure bred stock is preferred, especially those of the American class.

The Plymouth Rock is still a great favorite in the open market, but others of the same class find as ready a welcome. Some of the

Mediterraneans make good squab broilers, but as roasters they are not desirable nor profitable. Where Mediterraneans are chosen, it is for the purpose of producing eggs for market, no consideration being given to flesh production. Without question, the Mediterranean type is the most economical egg producer, even as the dairy type of cow is the most economical butter fat producer. Without discussion of the "best breed" question, it must be admitted there are "best types" for certain purposes.

The amount of land, size of units run in a flock, whether the enclosure or free range system is to be followed, and, as above mentioned, kind of products desired, all should be carefully considered before choice of breed is made.



Brood Coop

BROODING

Only a few years ago the rule was that not more than 50 chicks should be placed in a brooder. It is true that crowding is the cause of much mortality, but heat is the best preventative for crowding. We also believe heat to be the very best preventative of bowel disorders in baby chicks. Too much heat cannot be supplied if care is taken to furnish a way of escape. Chicks will go only as near the source of heat as is necessary for comfort.

The brooder should be as warm as was the incubator from which the chicks were taken. If the brooder is of the hover variety, allowing the chicks to come close to or go from the heat, it is wise to furnish a surplus of heat; if the brooder is of the box type, care must be taken to have the temperature high enough, uniform, and at the same time to furnish plenty of fresh air. Chicks will not bunch up if they are warm enough. They will not cry if they are happy and usually cry on account of being cold.

BROODERS

The large unit brooders, heated by oil burners or by coal stoves, capable of furnishing warmth for from 500 to 1,000 or even more chicks, seem to be the coming brooder where larger numbers of chicks are raised. This Station has not tried them out, but feels satisfied that they are satisfactory because of the good words spoken for them by many Colorado poultrymen. It seems that with this type of brooder especially, plenty of heat must be furnished to prevent crowding. Certainly the brooder house should be well built for use during the early part of the season.

FEEDS AND FEEDING

Variety is the price of health. If the hen has considerable range, grain is all that need be provided during the summer months. In the winter, and also if confined in summer, everything must be provided. For best results fowls should have grains, greens, meats. How much of each cannot be stated, but equal amounts of two or three grains, whole, and the same proportions in the mash, will be found not far wrong. Probably too much wheat and not enough corn is fed to our poultry in the irrigated sections. Corn is our most important poultry feed and should always appear in the ration. Oats, because of often being of poor quality, is not as desirable as corn or wheat, and may be fed in smaller quantities, or eliminated. Milo and kaffir are good feeds, but not quite as valuable as corn. When they are purchased, it should be because they are lower in price than corn.

There is no excuse for not furnishing plenty of greens to poultry in winter. When they have free access to the alfalfa stacks they are pretty well supplied. However, root crops will add to the value of the feed because of their succulence; they can be raised in abundance or can be cheaply bought. Mash once a day, especially in cold weather, is not only an appetizing meal but a means of utilizing many waste products. Small potatoes and cull onions, cooked and mixed with bran and shorts, make an excellent and cheap ration.

A good method of feeding is to furnish wheat or oats in the litter for the morning feed to induce exercise; the mash at noon when loafing is least objectionable; an abundant feed of corn, kaffir or milo at night.

The best feed on the farm and the one least supplied to the hens is milk. It is preferable to commercial meat feeds when it can be had without stint. It was determined by experiments at the Purdue Experiment Station that hens, furnished all the buttermilk, sour milk or sweet milk they wanted, did as well as those furnished more expensive feed in the form of beef scrap.

FEEDING BABY CHICKS

It might be very appropriate to say "feed them anything," better yet "feed them everything," for we find about everything being fed to

the little chicks. The following ration will be found to answer all purposes and can be modified or supplemented according to circumstances :

For a scratch feed :

10 lbs. cracked corn
5 lbs. oatmeal
10 lbs. cracked wheat

For a mash feed :

10 lbs. bran.
10 lbs. middlings
10 lbs. fine corn chop

A johnny cake made from the above mash mixture mixed with milk, and scraps from the table, will help to add variety to the ration. But what is considered the most important food for little chicks is milk, sour or sweet, but milk every day of the chick's life, from the egg to the table. With plenty of heat, plenty of grains and milk and a clean body, the chick will thrive.

DISEASES

Carelessness and neglect are usually the forerunners of disease in the flock. A spoonful of epsom salts in the mash for every 3 or 4 grown fowls, every week during the late fall and early winter months, is worth more than any dope for curing. Enough permanganate of potassium to give the water a rich wine color, during the same time, will help greatly to prevent diseases that often follow colds. Fowls should not be turned out when the ground is cold and wet; until the sun has warmed things up, they should be kept confined, busy hunting in the litter. Keep the flock thinned out to the capacity of the buildings. Weaklings should be removed. Lice and mites must be kept down. Just a little lard or vaseline smeared on the baby chick's head will kill the lice there; a vigorous fowl will look after itself in the "earth" bath.

The most dangerous enemy we have in roup. It attacks all sizes of chicks and fowls, and usually starts in with its deadly work in the autumn. Chickens should be removed from the small coops before the nights get sharp; the new quarters should be clean and roomy; they should be kept in during stormy weather; if weaklings have been eliminated, there is little danger of infection. If roup appears, the infected fowls should be isolated at once; bad cases should be killed and buried; those slightly affected should be sprinkled with insect powder to kill the body lice; their heads should be immersed in a 5% solution of some disinfectant, such as zenoleum or creolin, and for a few days they should be fed lightly. Fowls are subject to bronchitis, pneumonia, tuberculosis, chicken-pox, and liver troubles; they have bumble foot and scaly legs, and are sometimes crop bound, and have almost as many disorders as people. If we tried to cure all their ailment, we would have but little time for anything else. After trying many remedies, experience usually teaches that prevention is about the only cure worth while with a fowl. The Veterinary Department of the College will be glad to handle a limited number of "cases". Please write to Dr. I. E. Newsom, care Colorado Agricultural College, who will tell you how to ship sick or dead fowls.

MARKETING

Colorado markets are not particular as to color of the egg shell, neither do they discriminate against the white skin of fowls. To obtain the best prices eggs should be clean, uniform in size and color, shipped in clean carriers. Denver markets, however, do object to the quality of Colorado eggs in late spring and early summer. No one is quite ready to give the cause nor to suggest a remedy, but the State Agricultural College intends to investigate this matter during the next season. The eggs show bad under the candle; the yolks appear brown spotted and very dark, and the whites are very thin and watery. These eggs are not desirable for storage purposes, which means that Colorado farmers will receive less rather than more for early summer eggs than is paid to the Kansas farmers. The best way to shut out outside products is to produce better quality.

The markets prefer fowls alive. Broilers should be $1\frac{1}{4}$ to 2 pounds in weight and the more uniform in size and appearance the more desirable. Roasters and hens should be large to obtain the best price, as much as 3c or 4c more per pound being paid for those over 5 pounds than for those under 4 pounds. There is a time, a best time, to sell; one should study the markets; Does it pay better to sell a 2 pound broiler at 50c or to keep it 3 or 4 months and then sell it at 5 lbs. for 50c or 60c? Shall I sell a hen as soon as the season's work is over, from June to September, at 13c to 15c or keep her 4 or 5 months longer in idleness and then sell her for 10c or 12c? Too little attention is paid to the matter of marketing and many of our farmers are selling at the wrong time.

Poultrymen can with profit encourage their customers to preserve eggs for winter months, thus stiffening the market when eggs are most plentiful and also relieving the demand for eggs when eggs are scarce, thereby better satisfying their trade.

The Parcel Post.—Some of our poultrymen are shipping their entire output of eggs by mail. A very successful plan is to ship to one person connected with a large business firm in Denver who stands responsible for the shipment. He distributes the eggs among his fellow workmen who pay him for their share of the eggs. This is getting the producer and the consumer pretty close together and is working out very advantageously. The family trade is also proving profitable, being supplied by mail. Shipments are made once or twice a week and often include vegetables, fruits, butter, etc.

POULTRY SECRETS

There are no secrets which one needs to buy in order to succeed in the work. All the so-called "secrets" and "processes" can be procured through experiment station and government bulletins. It is not the breed, nor the feed, nor the house, nor the care; not any one or two of these factors that count, but a careful application of thrift and industry.

Continued selection of the best, elimination of the weaklings, eternal cleanliness, comfortable shelter, plenty of fresh air, sunshine

and range, a variety of good, nourishing, succulent feeds; all thoroughly mixed with love for the work and faith in the hen, seasoned with common sense and business ability; these are the great secrets of success with poultry.

THINGS TO REMEMBER

To build in a well drained spot; avoid dampness within.

To face the house to the south; sunshine within is a good medicine.

To make the north, east and west wind-proof; plenty of openings in the south for fresh air. Fresh air is health.

To furnish for small flocks 4 to 5 square feet floor space for a hen; for larger numbers 3 to 4 square feet. It never pays to crowd. Crowding encourages disease.

The convenience of the care-taker; roosts on a level and removable; nests and other appliances so arranged as to make cleaning easy.

To have the floor well covered with clean litter.

To make a wide doorway; much hard work can be eliminated by wheeling in clean sand or dirt for the floor, and by wheeling out old litter and the droppings

Hatch Asiatic breeds in March.

Hatch American breeds from March 15th. to April 30th.

Hatch Mediterranean breeds from April 1st. to May 15th.

Hatch the year's crop as quickly as possible.

For two or three weeks keep the hen confined; let the chicks run.

Early hatching means broilers at a high price.

Early hatching means early laying pullets.

As the chick grows after broiler size the price declines.

Molting is a natural function. Do not overfeed a molting hen; make her hustle for her living.

Furnish variety for the fowls; every farm has it.

Lice on the chicks means no chicks.

Cold feet require fuel; feed is the fuel.

Milk—sour milk, buttermilk, sweet milk; nothing better.

Chilling, lice, mites—the chick's greatest enemies.

Market prices for good poultry products are good; keep down cost of production.

Count the loss as well as the profit. What is the non-producer costing you?

Do not forget water, lots of it, fresh.

When eggs come soft shelled, furnish lime.

If you like the flavor, eat the dirty eggs, but don't sell them.

Kill the weaklings.

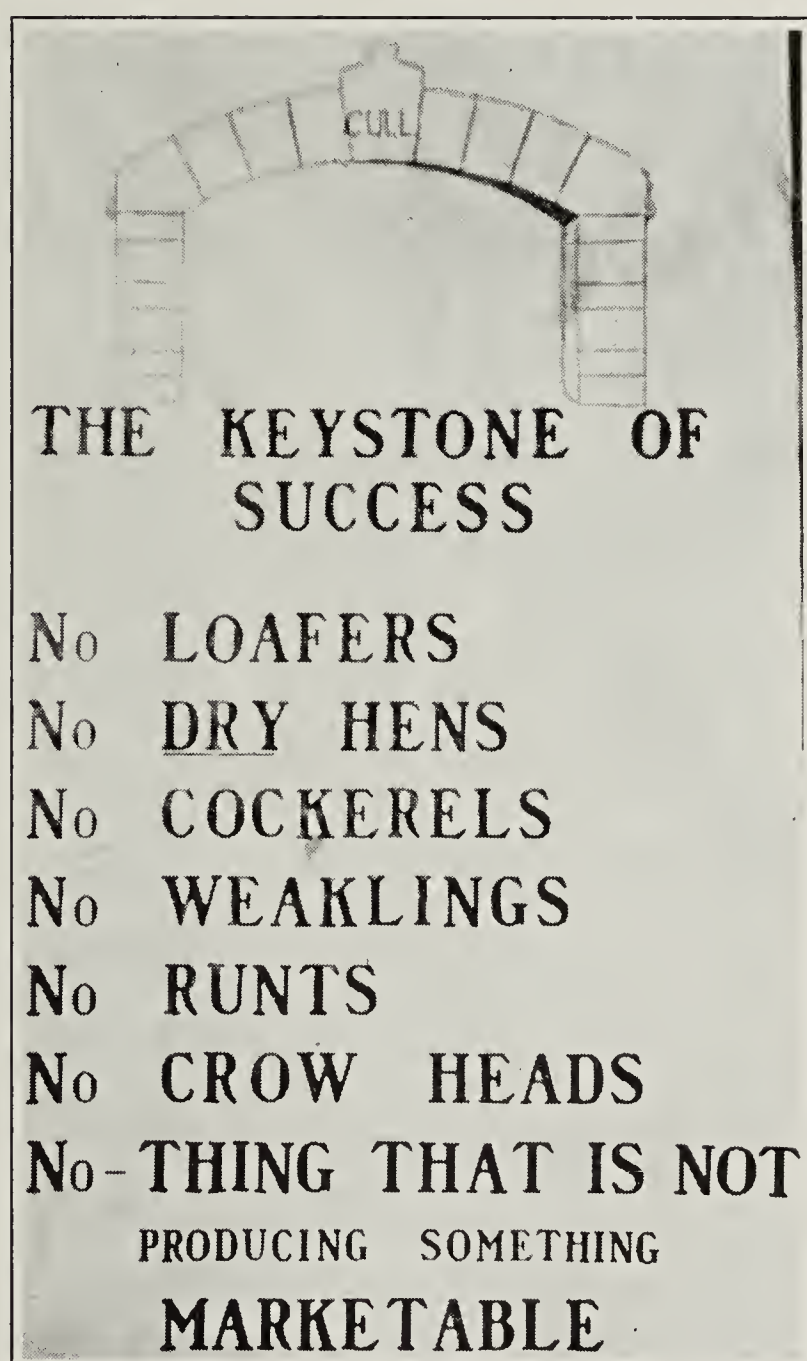
Use the "crow-heads" for fertilizer.

Keep after the lice.

Mate pens at least a week before using eggs for hatching.

On the average:

A hen will eat in one year	60 lbs. grain
A hen will loaf in one year	120 days
A hen will lay in one year	110 eggs
A hen will cost in one year for shelter	10 cents
A hen will cost in one year for labor	25 cents



The Agricultural Experiment Station

OF THE

Colorado Agricultural College

FORAGE CROPS

FOR THE COLORADO PLAINS

—BY—

ALVIN KEZER



PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS COLORADO
1915

The Agricultural Experiment Station

FORT COLLINS, COLORADO

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FORAGE CROPS FOR THE COLORADO PLAINS

By Alvin Kezer

INTRODUCTION

It is the purpose of this publication to treat of some of the fundamental considerations necessary for the growing of forage crops on the Colorado Plains outside of the irrigated districts. The farming conditions are those commonly called "dry farming." Considerable experimental work has been done from time to time at Cheyenne Wells, Monument, by the Government at Eads and Akron, at Julesburg, and cooperatively at a number of other points. The experimental work has been supplemented by the work of different field agents from time to time, and several years acquaintance and observation thru this territory.

CLIMATE AND TOPOGRAPHY

The Colorado Plains constitute a part of what is known as the Great Plains area. They lie east of the Rocky Mountains and extend from the base of the foothills to the state line. These plains are, for the most part, smooth to rolling prairies. Thru the northern part, the Platte River has cut its valley, which gives rise to an extended depression extending north-easterly from the city of Denver to the state line. Thru the southern part, running almost due east and west, the Arkansas River has cut its valley, creating a depression and many soil modifications due to stream flow and the deposition of soil material from flowing water. The Divide region between the Platte and Arkansas drainage reaches a considerable altitude, above 9,000 feet. This divide decreases in altitude and sharpness of slope towards the east, being much flatter as it approaches the eastern border. The streams cause more or less breaks and some rugged features in the otherwise general smooth to rolling appearance.

The climate is mild-temperate, but subject to very sharp extremes of both heat and cold, moisture and dryness.

The normal rainfall as shown by the Government and State rainfall records, varies from a minimum of approximately 8 inches to a maximum of about 18 inches. In years of drouth the rainfall is very much less than normal, while in years of heavy precipitation—so-called wet years—rainfall greatly exceeds the normal.

The region is one vast, unprotected, treeless plain, and as a consequence it is subject, especially during the spring and fall months,

to violent winds. A considerable knowledge of the climatic features to be met is essential because it has a strong bearing upon the cropping possibilities of the region.

The altitude of this region is high, varying from a minimum of about 3,500 feet to over 10,000 feet. These altitudes are associated with short seasons and cool nights.

SOILS

For the most part, the soils are exceedingly rich and deep. There are, however, localities in which the surface soils are underlaid close to the surface with the country rock. This country rock is quite variable in its exposure—different geological formations are exposed in different localities. For the most part the soils are rather light in nature, running from sandy loams to as coarse as gravelly loams, sandy and silt loams predominating. There are an extremely small number of places where heavy clay and adobes prevail. The acreage, compared to the 22,000,000 acres of plains lying in Colorado is relatively small.

In the eastern and northeastern portion there are some areas of almost pure sands. These have been blown about by the winds to form sand dunes or sand hills. Sand dunes appear at other points in the Colorado Plains, but in less extensive areas.

In some sections the soils are almost pure silt, making loams of great depth, more available water relations, and amount of rainfall considered, unusual certainty of productivity.

The U. S. Bureau of Soils has made surveys of soil types in Larimer and Weld counties, and in the Arkansas Valley. These surveys and a careful checking of the same territory by later workers, show that the prevailing types in those different sections are largely sandy loams and silt loams. Those soils which have the proper physical texture and great depth are the ones which are capable of supporting a dry farming population. No matter how favorable the texture may be, if the surface soil is underlaid at a short depth with impervious clay layers, or with one or another of various beds of country rock, or with gravel, it is unfit for dry farming purposes except in the very wettest years, because such shallow soil is not capable of supporting vegetative growth thru prolonged periods of drouth.

In the sand hill regions the tendency to blow in the prevailing high spring and fall winds is so great that except in wet valleys, the soil should not be broken up. An effort should be made to make use of the native pastures and to increase their carrying capacity by intelligent grazing methods, by seeding in such crops as Sweet Clover which seems to thrive under such conditions. Even the sandy loams and silt loams if plowed up so as to dry out, and if finely pulverized at the surface, will blow in a very short time after being broken up—that is, as soon as the organic matter contained in the fresh sod is reduced in amount. It is essential, therefore, on all lands to carry on some system of farming which will assist in keeping up the organic matter content; to resort to such a system of plowing and cultivation as will leave the immediate surface more or less rough and quite coarsely granulated.

If the surface is granulated from the size of small gravel up to the size of a walnut, there is almost no danger of its blowing. A finely pulverized surface will almost certainly blow, no matter what the texture of the soil.

On all but the very sandiest lands, soil blowing may be controlled. Control methods consist of keeping the immediate soil surface rough on all plowed land and cultivated land not in crop. Anything which will break the force of the wind at the soil surface is effective. On many soils where the tendency is to blow badly, fall plowing can not be done. Usually, however, such lands may be fall listed crosswise of the direction of the prevailing winds. The furrows furnish sufficient protection to largely prevent blowing.

When a crop is to be planted, other protection is sometimes necessary. One successful method is to plant grain in strips alternate with listed land. Corn or some of the sorghums are planted in the listed furrows. Having these strips at least a rod wide and placed from ten to forty rods apart furnishes protection against soil blowing on any soils except the purest sands.

DRY FARMING

The commonly accepted definition of dry farming is taken to be the production of crops without irrigation in a region where the rainfall is between 10 to 20 inches per annum. Much work has been done in an attempt to find adapted crops for dry farming; to find out the principles of water movement; the principles of moisture conservation; and what practical methods of plowing and cultivation must be followed to get the best results. At first, both practically and scientifically, the effort seemed to run itself to the production of grain crops or a knowledge of the principles underlying their production. Long experience, however, has shown, and a study of the climatic and moisture conditions of the soil bears the opinion out, that any system of farming which depends upon the production of cash grain crops on dry lands of the Colorado Plains, is destined to failure in all but a very few localities.

The crops which grow and thrive best, which are most certain of reaching harvestable maturity, are forage crops. Owing to their bulk and to the varied character of these crops they can not generally be marketed directly for cash. They must therefor, be fed to some kind of livestock and the livestock marketed if a permanent system of agriculture is to be established and maintained in this region. With the proper use of forage crops and livestock, with perhaps the growth of small acreages of the best adapted cash crops, and the use of livestock, a permanent system can be established. The cash grain crops will not bring in money each year, but occasionally they will make an agreeable addition to the money supply of the family. The main dependence, however, must be placed upon forage crops marketed thru livestock.

GENERAL FARM PRACTICE AND MANAGEMENT

Dry farming at its best is serious business. As a consequence, there are certain fundamental considerations which the settler should bear in mind. A well for domestic water supply is absolutely essential. If such domestic water supply can not be obtained upon the land or immediately adjacent to it, other features would have to be extremely desirable to make it advisable to locate a home. The production of crops is more or less uncertain and the prospective settler should by all means bring sufficient capital in money, or in money and materials, to carry him thru at least one year until production can be started.

For the most part the plains are treeless. In the building of a home, one of the first things, after the house and sheds for livestock are provided, should be the making of some provisions for trees. Where land is properly prepared and properly cultivated, trees can be grown almost anywhere on the plains, providing they are given sufficient space. The moisture supply on dry land soils is always less abundant than it is in the humid regions; consequently the trees should be set much farther apart. The sod should be broken up at once in preparation for planting trees. A strip should be plowed at least twenty feet wider than the expected space which the trees will occupy. This should be kept free of weeds by plowing or other form of cultivation to permit the accumulation of water. Sometimes the soil can be sufficiently moistened, when such clean cultivation is followed, in one season to permit perfect safety in tree planting. Sometimes two seasons must elapse, and in extreme seasons as many as three. The ground should be ready and have sufficient moisture before trees are put out.

The planting of trees will make it possible to have some shade about the home. In addition to this, trees will break the dreary monotony of the plains—a monotony which is very real to all those not born and bred plainsmen. The women folks of the family are especially susceptible to this loneliness because of the isolation and difficulty of social relations with the neighbors.

The dry farmer should make provision for a garden somewhere near his well. If a good well is present for domestic water supply it can be used, especially if a little storage is possible, to insure a good small garden if the water is properly applied at the right time.

The dry farmer should by all means plan his cropping system so as to grow feed for at least a few chickens and pigs, so that the family living will be insured. The type of other livestock which he chooses to grow will depend a good deal upon his location, as either dairy or meat animals can be made profitable. There will be seasons when an abundance of feed will be produced. There will be other seasons when the amount of feed produced must be very carefully husbanded in order to permit existence; consequently, sooner or later the dry farmer should come to the proposition of saving all of his feed, and in extra

good crop years to store up excess feed to tide him over the lean years which are bound to follow one season or another.

The wide use of the silo is bound to come as a part of this development, because it permits all, or practically all, the feed grown to be stored in available succulent condition for future feeding. In 1912 the Experimental Sub-Station at Cheyenne Wells produced feed enough to have carried the herd on the land at that time for a period of two years. The silo capacity was limited to two pit silos at that time. They were filled to capacity, but they were only capable of carrying the herd thru the winter and the following early summer. In 1913 by saving every bit of feed that it was possible to save and putting it into the silo, it was not possible to quite fill even these two silos. In 1914 two more silos were put down so that now we have capacity enough to carry the normal regular herd thru a period of two years if extreme conditions should appear.

No method of dry curing of the crop is so efficient that it does not waste at least as much as thirty per cent. In the dry windy conditions which prevail as much as eighty per cent of the feed value may be lost. If put in the silo at least ninety per cent should be saved under normal conditions. In other words the loss need not be over ten per cent and often will be less than five per cent. The silo making possible this great saving in feed is bound to have a much greater use upon the dry farms.

In many places dry farmers are making use of open range available to carry their stock in the summer. During some seasons this open range will be cut short by extreme drouth so that the animals lose flesh or fall off in milk production according to the kind of animals kept. If the dry farmer had a silo at this time he could open the silo and feed some silage during the period of short pasture and keep up his gains on beef animals and his milk production on dairy animals.

The entire system can be summarized then, briefly as follows: Forage crops are best adapted to the soil and climatic conditions. In the best management they should be grown and placed in the silo to be fed later to livestock. Grain farming should be entirely supplementary to the general system. Of the grain cash crops which may be grown, we have winter wheat, flax and Mexican beans. With winter wheat and flax especially, the farmer should look upon the proposition as a chance for getting something extra, his living and his main returns to be obtained from livestock which are fed upon forage crops.

ALFALFA

Farmers, experimenters and others have long recognized the need of a reliable legume crop that would supply forage for the dry farming sections of the plains. Alfalfa was tried and pronounced a failure by most of the persons who tried it. The fault was not entirely that of the alfalfa. In attempting to produce alfalfa, planting was done in

exactly the same way, using the same amount of seed as was used in irrigated and more humid regions. Frequently also, improper and unadapted varieties were used.

In the dry farming sections of the plains the water supply is always limited, except in an occasionally unusually wet year, and thick planting of alfalfa, such as thrives under irrigation or in humid conditions did not survive because there were more plants upon the land than there was soil water upon which they could draw. Failure, of course, followed.

In a practical way the Brott Brothers of Sextrop, Nebraska, just across the northeastern Colorado line, were the first to successfully solve the difficulties. Their method of meeting the difficulty was to plant alfalfa in rows and cultivate. Different distances to plant the rows were experimented with until finally it was decided that under dry land conditions it was necessary to put the rows from 3 to 3½ feet apart.

J. E. Payne, working as Agronomy Field Agent of the Experiment Station, worked out six or eight years ago the fact that alfalfa must be planted thinly on the land if it is to survive in the dry land sections. Under his direction a number of farmers made broadcast plantings using 3 and 5 pounds of seed to the acre. The three pound seedings were the most successful. Definite experimental work since that time has shown for Colorado conditions that it was necessary to plant alfalfa in rows in order that the number of plants might be easily limited on the land to prevent other plants coming in and competing for a part of the moisture supply, and the rows cultivated to keep down weeds.

In the past four years, successful row plantings on dry lands have been made in Weld, Larimer, Sedgwick, Elbert, El Paso, Lincoln, Cheyenne, Kit Carson, Otero, Crowley Counties and a few other localities. Experience with these plantings has been that row planting is a success for seed production. When it is considered that on an average the grower can count on a yield of about three-fourths of a ton of cured hay per annum for dry land conditions, it must be acknowledged that row planted alfalfa gives promise of having a very important place among the forage crops of the dry lands.

Varieties.—Experimental work has shown that the less hardy common alfalfas are absolutely no good for the dry lands. Work of the Experiment Station has shown that Baltic, Grimm and Hardy Turkestan alfalfa are the best varieties, in the order named. The Baltic and the Grimm are very much alike—in fact, the Baltic is a selection from the Grimm. These two sorts are very superior, both for hay and seed production wherever we have experimented with them on the Colorado Plains. Next to these varieties just mentioned, it has been found that if common alfalfa is used, the seed of which is taken from fields which have stood eight or ten years, that fairly good results are always obtained. Where the field of alfalfa has stood for ten years, most of the weak and non-hardy plants have been killed out so that seed is obtained only from plants capable of enduring the con-

ditions. When selected in this way seed may be taken from irrigated regions.

Preparation of the Seed Bed.—Alfalfa is a crop that is going to occupy the land for some years, so every possible precaution must be taken to get it started with the desired stand. In order to do this the seed bed must be prepared. It is necessary to get moisture into the seed bed before it is safe to put in the seed. There should be moisture enough to carry the crop for some months without additional rainfall. To accomplish this purpose the soil should be moist to a depth of at least two feet before plantings are made. Of course it is understood that rains are always liable to come and wet up the soil. It is also well known that rains may fail to come for periods of three months. In order to be on the safe side, alfalfa should be planted only in soil that is properly prepared, with the right amount of moisture to start the seed off and keep the crop growing for a period of at least two or three months without help of rainfall. In preparing such a seed bed it is frequently necessary to adopt the summer fallow. The land should be plowed thoroly and deeply. It is well to disk the soil immediately after the plowing in order to flatten the furrow slice.

Alfalfa does best on land which has been plowed and then afterwards well packed. The surface should be left granular rather than fine and dusty. The granular or "small cloddy" surface not only takes up the moisture which falls better than a dust surface but it protects the moisture supply present much better and is in very much less danger of blowing. When the seed bed has been properly prepared and has a sufficient supply of moisture present, the soil is ready for planting.

In most of our plains districts the rainfall is such that the best moisture conditions prevail between March and the first of July. On a properly prepared seed bed seeding may be done with safety any time from early in April until the first of July—preferably April and May seeding if the seed bed is in condition, because the alfalfa will grow better if it has a root system started before hot weather of July and August, and planting should be done in rows 3 to 3½ feet apart.

Where the prevailing winds are north and south the rows should be planted east and west. In other words, wherever the lay of the land will permit, the rows should be crosswise of the direction of the prevailing winds.

Seed should be put in with some sort of a drill. It is possible to rig a corn planter by using extra seed cups from some of the grass seeder attachments with which many of the modern drills are equipped.

With Baltic and Grimm seed, if the soil is properly prepared, one-half pound per acre, with rows 3½ feet apart is sufficient. With most methods available probably about two pounds will be planted, because of the difficulty of regulating the drop so as to drop less. Careful, patient, mechanical farmers can devise ways of reducing the rate of

planting. For many of our experimental plantings, Mr. P. K. Blinn devised an attachment which could be put on the corn planter and beet drill, or even attached to a grain drill. We obtained some of the drop cups manufactured for the grass seeder attachments of one of the standard makes of drills. These were provided with individual seed boxes which were mounted upon a drive shaft in such a way that their width was readily adjustable. Then by means of a couple of sprockets, it was possible to drive the drill from the shaft of a corn planter, grain drill, or a beet drill. With this device several hundred acres were successfully planted.* A number of farmers have devised ingenious corn planter attachments for row planting. If the soil has been properly prepared very little cultivation will be needed after seeding until the crop has gained some little size. If it is necessary to cultivate the plants while small, shields should be used on the cultivators. After the plants get above five inches in height, cultivation is easy. The cultivation given should aim to keep down weeds and to prevent the formation of a crust.

Harvesting.—When the row alfalfa is harvested for hay it is cut with a mower and put up in the same manner as any alfalfa. If there is dew present, the mowing should not be done until the dew is off. The hay should be raked before it has had time to do anything more than slightly wilt. Further curing is done in the windrow or cock. It can be done more rapidly than is possible in the swath. If left in the swath the leaves dry up almost at once leaving the stems full of water. If it can be raked into a loose windrow so that the leaves are partially shaded, the evaporation or drying will go on very much more rapidly, because the moisture will pass out thru the leaves more rapidly than it will pass thru the stems.

When harvested for seed it is necessary to determine at what time to cut. The aim should be to cut it at such a time as to get the greatest number of ripe seed pods. Unfortunately the seed pods do not all mature at once. Usually if the cutting can be done when about three-fourths of the seed pods are ripe the greatest amount of seed possible will be obtained. When cut for seed the mower is again the most desirable tool to use. If a buncher attachment is at hand the problem is easy, as a man can walk along behind the mower and move the bunches over so the horses in making the next swath will not walk upon the cut alfalfa. This precaution is rather necessary, especially in dry times, because if the horses walk upon the cut swath they will thrash out and break off a large amount of seed. If a buncher attachment is not at hand it will probably be necessary to either rake or lay over swaths with forks. The ripe swath can be placed in a loose windrow and allowed to cure there, or into small cocks. As soon as the stems are dry enough, it can be thrashed, or if thrashing facilities are not immediately available, it can be stacked in order to keep it in condition until thrashing can be done.

* The drill manufactured by the Columbia Drill and Planter Co., Springfield, Ohio, has a drop which can be successfully attached for seeding alfalfa in rows.

CORN

Corn is commonly considered a grain crop, yet upon the Colorado Plains it is one of the leading forage crops, and in many sections will be the leading grain forage crop. In the higher and moister sections, on the Arkansas-Platte Divide region, corn will produce a greater tonnage than any other similar forage. There are many other localities where it will out-yield the grain or forage sorghums. Where corn will out-yield such other crops it should be used for forage. It makes an excellent fodder where properly cured and when stored in the silo makes the very best silage possible. Corn can be grown in cooler localities than can any of the sorghums. It is probable, therefore, that corn will take the first place in the cooler and moister sections, while the sorghums will take first place in the dryer and hotter sections of our territory.

Preparation of the Soil.—The best method of soil preparation for corn depends upon the character of the soil, the rotation, and the crop which precedes corn on the land. If the land is rather light and sandy, fall plowing is not wise on account of danger of soil blowing. However, such lands may usually be managed so as to keep down weeds and put the surface in shape for catching winter and spring moisture. Where small grain or an early harvested cultivated crop preceded corn, the land may be double disked at once to kill weeds and put the surface in good condition for catching rainfall. Then, instead of plowing, the land is listed. Experiment shows that this practice stops danger of blowing. In the spring, just as early as possible, the middles are broken out.

Listing tends to lengthen the time required to develop corn to full maturity, consequently, planting corn on listed land is not always advisable. Where, on account of the difficulty of maturing listed corn, it is advisable to surface plant, the listed ground is worked down by disking and harrowing.

Often on the lighter lands, experiment has shown a system may be followed which keeps down weeds and conserves moisture at a great reduction of labor without reducing yields. Thus the cost of production is kept down. The suggested system is carried out as follows, starting the system and rotation with summer tilled land. The first crop put on is winter wheat. Immediately after the binder, the land is double disked for the double purpose of killing all weeds which spring up and to put the surface in good condition to catch rainfall. The following spring the land is double disked early, then corn or other cultivated crop is planted. Following corn, small grain is planted. The yields of grain after corn or other clean cultivated crop are nearly as large as after the fallow. As this last small grain crop is cut, the land is double disked. It is then allowed to lie. The following spring, as soon as weeds start, the soil is again disked to kill weeds, preserve tilth and the better to catch rainfall. In June and July the land is plowed thoroly and deeply, disked and harrowed immediately behind the plow. Winter wheat is planted in September and the rotation is under way again. Such

management has been found more successful on many soils than more frequent plowing and the cost of following the system is very low.

Upon the soils which give better results from plowing each season, the soil should preferably be plowed early in the fall, the earlier the better.

Over most of the Plains area, corn can be planted by the 10th of May. In the extreme southeastern part of the Colorado Plains, planting can be done the last of April or the first of May. In the extreme eastern part, some planting may be done by the first of May, but usually it is not wise to put in corn very much before May 10. Nearly always the Plains are subjected to a frost about the middle of May and there is little use of getting corn in prior to this danger period for frosts. By this time, the ground has become somewhat warmed so that the crop will start off readily.

Corn should be planted in rows $3\frac{1}{2}$ feet apart. If drilled on the dry land there should be one seed about every 18 to 22 inches. If check-rowed, only two kernels to the hill should be planted.

In very dry localities where experience shows difficulty of getting sufficient moisture to produce a crop, the rows may be planted 7 feet apart or double the usual distance. When thoroly cultivated, such wide planting insures a crop in years when ordinary planting fails. With such wide planting, the seed may be put in a little thicker, 15 to 18 inches, in the row when drilled. This method of planting has been tried with success in several Colorado Plains localities.

Varieties.—There are an infinite number of corn varieties, but owing to the altitude and the shortness of the season, only the short season or so-called northern corns should be planted. Of the native varieties which have been tried out, the Swadley Dent, the White Australian Flint, and Parson's High Altitude corn have given very excellent results. For the more northern portions of the Colorado Plains area, Pride of the North, Minnesota Number 13, Minnesota Number 23, and Wisconsin Number 7 have been tried and have given good results. Of the imported corns, Minnesota Number 13 and Wisconsin Number 7 have been among the best. Minnesota Number 23 has not been tested a very long period of time, but gives promise.

For dry land forage purposes, it is unwise to plant the large-eared, late maturing types of corn. They are more subject to injury, will not produce as heavy yields and will not mature seed with any certainty.

Cultivation.—The major portion of corn cultivation should be done in the preparation of the seed bed. Cultivation after planting should be relatively shallow and frequent enough to prevent weeds gaining a foothold, and prevent the formation of a crust. For this purpose, the use of a type of cultivator having numerous shovels to the gang should be used. Numerous small shovels work up the entire surface thoroly and do a better job than the larger shovels as ordinarily used. Cultivation should be approximately four inches deep. It is seldom wise to go deeper, as root pruning becomes severe and very injurious, especially in dry times.

Harvesting.—For forage purposes it should be the plan of the dry farmer to put his corn crop largely in the silo. Corn should be allowed

to mature pretty well, at least to mature until the ears are well dented and glazed before the crop is harvested, as it will make better silage and a greater yield of feed if harvested at this time. It will not be harmful if some of the lower leaves are dry, because water can be run into the silage as the silo is being filled.

If cut for fodder it should be cut at about the same time as for silage and put at once into shocks. As soon as cured it should be taken in from the field and stacked in order to reduce the waste from the dry, high winds of winter to as low a minimum as possible. With the silo, it is possible to save ninety to ninety-five per cent of all of the feed produced in the field. With the best methods of dry fodder making, not over seventy per cent will be saved, and there will be a great deal more waste in feeding as the animals will not eat nearly so much. Often where the crop is harvested by cutting and shocking, weather conditions will be such that as much as eighty per cent may be lost, altogether too high a loss to be permitted where forage is as scarce as it is upon the ordinary Plains farm.

SORGHUMS

Two kinds of sorghums are commonly grown. Both have about an equal resistance to dry weather and drouthy conditions. These are forage, or saccharine sorghums, and grain, or non-saccharine, sorghums. The latter are distinguished from the saccharine sorghums in that the juices are not sweet. They are ordinarily called grain sorghums because they produce heavy yields of seed or grain which is well adapted for feeding purposes. The sorghums have one very valuable characteristic—in drouthy periods they will cease growth and unless the drouthy period is exceedingly prolonged, will recover and continue growth if moisture comes later. The sorghums have a very large place in the forage crops of our dry land regions because of their ability to withstand drouth. They can not be successfully grown in some localities because of the cold climate resulting from the high altitudes. Where the sorghums will out-yield corn, they should be grown for forage purposes in preference to corn.

Forage Sorghums or Sorgos.—The forage sorghums can be grown practically all over the Colorado Plains. In some localities near the foothills and in some localities on the Platte-Arkansas Divide, the altitudes are too high and the climate too cool for the best development of even the shortest-season sorghums.

There are a large number of varieties and types of sorghum. Practically only two types are adapted to any of our regions. These are the Ambers and Sudan Grass. Of the Ambers we have Black Amber, Red Amber, and White Amber. The White Amber was produced by selection by Mr. Freed of western Kansas. It is called in many sections and in some Government literature, "Freed's Sorgo."

Sudan Grass is not commonly called a sorghum, but for the purpose of this bulletin, it can be classed with the sorghums. It crosses

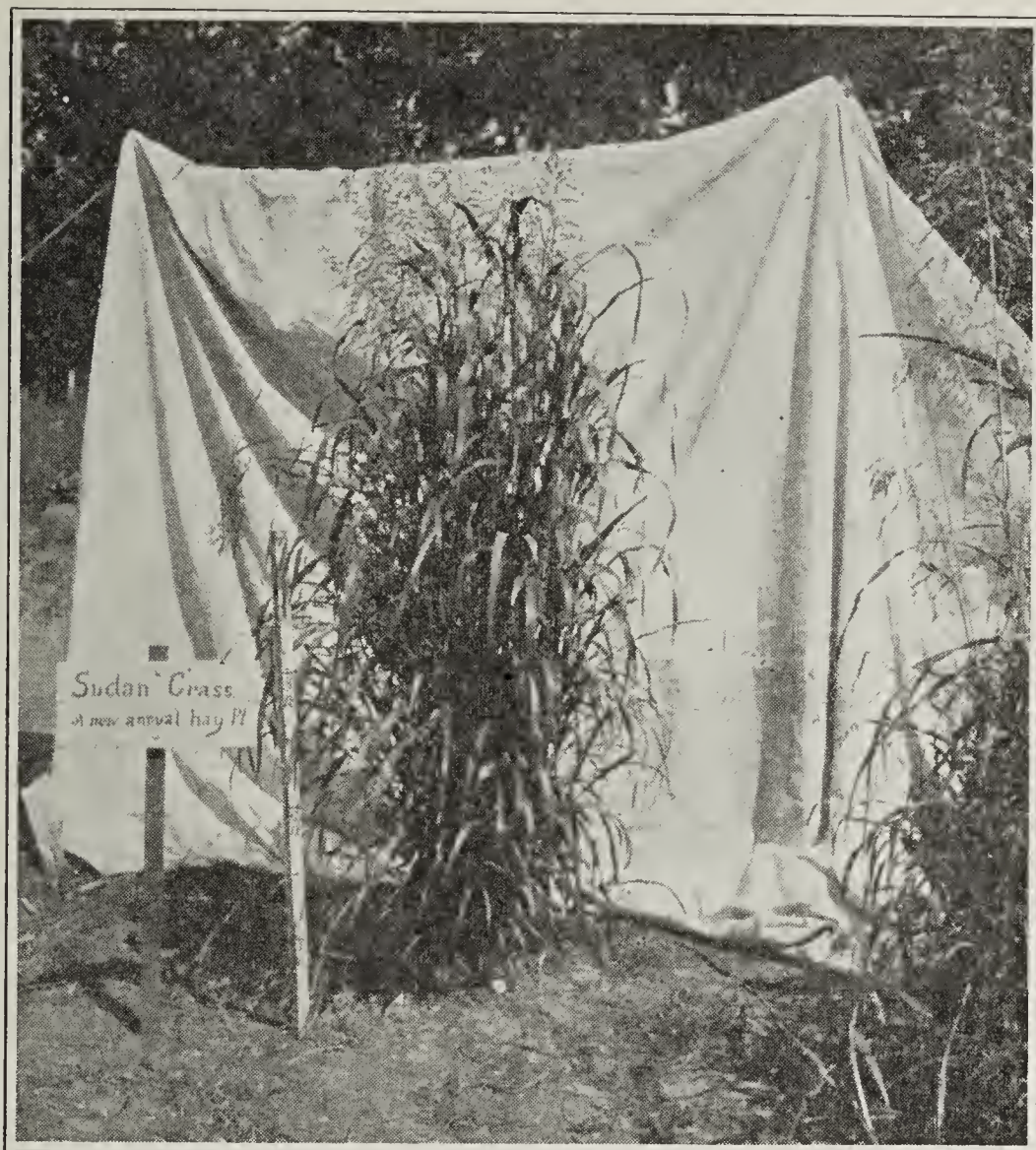


"Freed's Sorgo" grown at Akron, Colorado

readily with the Ambers or other sorghums, showing its close relationship.

Of the Ambers, the Black is the best variety. Altho in our experimental work at Cheyenne Wells, the White did well, it was not equal to our local strains of Black Amber. The Amber sorghums are best adapted to the southeastern portion of the State although they do well in the extreme eastern portion. They are less well-adapted as the altitudes rise close to the mountains, but even here they may be grown to some extent.

Sudan Grass has been tried in the State for 3 years. It was imported from Khartum in 1909. Sudan is a province in Central Africa, of which Khartum is the leading city. On this account the Department of Agriculture officials called the grass Sudan Grass. This grass has been tested for 3 years in Colorado and has given promise of being the best adapted hay crop of the forage sorghum types. It matures in a shorter season than Amber, stands drouth well, and grows vigorously. Its yield will, of course, be largely according to the moisture supply available and it will vary from 1 to 8 or 9 tons. The latter yield is only possible under irrigated conditions. Sudan



A single Sudan Grass plant, 7 feet high, showing heavy stooling habit.

Grass is not adapted to the higher altitudes next to the foothills nor in the Platte-Arkansas Divide, but is adapted to the rest of the Colorado Plains.

Preparation of the Soil.—The soil for sorghum should be prepared the same as for corn. Owing to the fact that all of the sorghums are what might be termed hot weather crops they require a warm soil before it is safe to plant. This planting should follow corn planting, usually from the 15th to the 20th of May is a safe time. Planting may even be delayed until early in June.

If seeded broadcast 20 to 30 pounds of Amber will make a thick enough stand. In most of the dry land regions, it will pay however, to plant the sorghums in rows so as to permit of cultivation. Six to 15 pounds per acre in rows, according to width of rows, will be amply sufficient upon most soils. Sudan Grass is smaller seeded and consequently a fewer number of pounds will do. If planted in rows 3 to 6 pounds will make a sufficiently heavy stand. If planted broadcast 10 to 15 pounds is abundantly sufficient.

Not Safe to Pasture.—Owing to the fact that the sorghums develop a poisonous principle which causes the liberation of hydrocyanic acid, commonly called prussic acid, it is unsafe in dry land regions to pasture with livestock. This poisonous principle seemingly



Sudan grass, 7½ feet high, grown near Rocky Ford, Colorado, on irrigated land, but without irrigation. Seasonal rain fall of 11 inches. Seeded May 15, photographed July 30

does not hold its effectiveness when the crop is cut and made into hay or made into silage. In other words changes occur so that the poison is no longer injurious.

Harvesting.—If not planted too thinly Amber Cane or Sudan Grass can be mowed and cured as hay. Either of these crops can be allowed to mature to be put into the silo if conditions warrant. When made into hay the crop should be raked, after allowing partial drying in the swath, immediately cocked and allowed to cure in the cock. Often Cane and Sudan Grass may be harvested with the grain or corn binder. The bundles are much more easily handled than the loose hay.

GRAIN SORGHUMS

The grain sorghums for the most part require a longer season to properly mature than Amber Cane or Sudan Grass. The following varieties of grain sorghums have been tried in an experimental and



Kafir grown at Akron, Colorado

practical way: Kafir, Milo, Kaoliang, Shallu, and Feterita (Sudan Dura). Each of these crops is represented by a large number of varieties.

Of the Kafirs, the Black Hulled White Kafir has been the best. Black Hulled White Kafir can only be matured in Colorado in the extreme southeastern part of the State and in a narrow belt extending along the eastern border practically as far north as Wray. It can be used for a forage considerably further west.

There is only one type of Milo that should be grown in Colorado, and that is the Dwarf Yellow. The tall Milos require too long a season. Dwarf Yellow Milo, in Colorado, is the earliest maturing of the grain sorghums and can be grown farther north and west and at higher altitudes than any other grain sorghum, now grown. In Kansas, Oklahoma, and Texas, Feterita is as early or earlier than Dwarf Milo, but in Colorado the situation is reversed—Dwarf Milo, will mature in a shorter season than Feterita.

Brown Kaoliang is very promising for many sections. It has been possible to mature Kaoliang at higher altitudes and in cooler situations



Brown Kaoliang grown at Akron, Colorado

than other grain sorghums. It has about the same feeding quality and value as the Kafirs. Milo and Feterita are better adapted where the season is long enough to mature them. In very dry situations with excessively short seasons, Kaoliang may have a place. In such locations corn does not thrive and other sorghums are not adapted.

Shallu has been tried and gives some promise. At the present time, however, the Kaoliangs and Shallu can not be recommended for

the Colorado Plains as strongly as Kafir and Milo. It is advisable to confine the grain sorghum production largely to those two crops.

Feterita is a white seeded crop, resembling Milo very much, except that the heads are always erect. Milo and Feterita belong to the group of sorghums known as Duras. Feterita was first tried in Colorado under the name of Sudan Dura. It is adapted to practically



Feterita grown at Akron, Colorado

the same territory that Milo is adapted. It is more drouth resistant than Milo, but is somewhat more adversely affected by the cool climate. As a consequence, Milo is to be preferred for planting.

Methods of Planting.—All of the grain sorghums should preferably be planted in rows whether it is expected they are to be used for grain or forage. The rows should be at least $3\frac{1}{2}$ feet apart. The rate of planting should be such that Kafir should have a space of 8 to 10 inches between plants—in very dry situations 12 to 15 inches; Feterita should be planted about as Milo. This rate of seeding will require 5 or 6 pounds of seed per acre ordinarily. For planting, an ordinary corn planter can be used provided with Milo plates. If Milo plates are not at hand, blank plates can be made into Milo plates by having a blacksmith drill holes of the proper size and spacing.

In the hotter, dryer sections of the Plains the grain sorghums will produce heavier yields of forage than corn. In such sections they should be grown for the silo or for fodder in preference to corn.

Harvesting.—When harvested for forage, these crops should be made into fodder, or preferably siloed. They should be allowed to

stand in the field under ordinary conditions until the seed is practically ripe. If put into the silo earlier, they will not make as much feed and there is a tendency to the formation of a sour silage.

In addition to being valuable for forage, the seed of the grain sorghums is valuable for feeding to all kinds of animals. It is possible to feed the seed of Amber Sorghum, but it is usually not advisable. The seed coat of Amber Sorghum is very hard and impervious to moisture. As a consequence Amber Sorghum seed is very much more difficult for the animals to eat than the seed of grain sorghums. Besides, the grain sorghums, where adapted, will produce a heavier amount of seed.

Milo and Fetera, when mature, have rather woody stalks and do not make a good fodder. They make a good silage, however. For fodder purposes, Kafir is a much superior grain sorghum. If hay alone is desired, it is better to grow Sudan Grass or Amber Sorghum than any of the grain sorghum varieties.

Harvesting for Seed.—When it is desired to harvest the grain or seed of the grain sorghums, it is best to allow the crop to get ripe, then, if possible, to cut with a binder and shock.

For feeding purposes the fodder having the ripe seed can be run thru a thrashing machine as soon as the stalks are well cured. Where the seed is to be used for seed, the heads should be picked out and stored under cover. Any of the grain sorghums, if stored in bulk, are very liable to heat, and only a very slight heating is necessary to render the germ infertile. Where a corn binder is not possible, the crop can be harvested by cutting by hand or by the use of a cutting sled. These methods are more economical of time and labor than to attempt to harvest the heads separately in the field. For seed purposes only it is possible to economically harvest heads from desirable plants in the field.

MILLETS

Owing to the fact that they will develop with relatively small moisture supplies and that they will mature in a short season, Millets must be considered among the important dry land forage crops. Millets, as are the sorghums, are "hot weather" crops and will not do well at higher and cooler altitudes. For the most part their place among the dry land forage crops is to furnish hay for horses, cattle and other similar livestock.

Varieties.—The varieties commonly met with on the Plains are the German, Common, Hungarian, Siberian, and Hog Millet. Hog Millet is grown more frequently for the grain than for the forage. In some sections it will produce quite heavy yields of seed. It is not widely adapted for Colorado Plains conditions. Where it is adapted it is worthy of a place in the rotation. Elsewhere, it should not be grown at all. Most of the sections where it does well lie in the northeastern part of the state.

In general, German Millet is recommended in preference to others. It grows more rank than the Common and consequently, where moisture supplies are fairly good, should be seeded a little thicker. If this pre-

caution is taken it will make as fine hay and usually a little more tonnage than Common. The other varieties are adapted, but do not possess any superiority. As a consequence, planting for hay purposes should be limited to the German and Common.

Preparation of the Soil.—The soil for millets must be prepared as thoroly, or more thoroly, than for sorghums and corn, as it is small seeded and must have a comparatively congenial seed bed if it is to produce a good crop. In order to accomplish the production of such a seed bed, plowing should be very early in order to allow the accumulation and protection of the moisture supply.

Seeding.—Millet should not be seeded until approximately the first of June for most of the Plains territory. It will not develop in a cold soil, and since it matures in a short season, planting can be delayed until the soil is thoroly warm, which is about the first of June. Preferably the seed should be put in with a press drill, using about 25 to 30 pounds of seed per acre. It can, however, be seeded by broadcasting and harrowing the seed in, or better still, rolling it in and following the roller with a harrow.

Harvesting.—Millet makes a valuable hay if it is cut at the right time. The right time is about the time the seed is in the milk. It allowed to mature farther than this the seed is liable to injure livestock to which it is fed. This is especially true of horses. When cut at the proper time, just as the seed is reaching the milk it makes a palatable, nutritious hay. The hay can be cut and allowed to partly cure in the swath, raked and cocked for complete curing. As soon as thoroly cured, it should be stacked to prevent loss.

SWEET CLOVER

In Colorado, Sweet Clover has been considered a weed and a serious pest until very recently. Many, however, are coming to recognize that this crop has value. As a soil renovator there is no legume which will give as desirable and quick results as will Sweet Clover. It finds an excellent place in pastures, and when cut at the proper time makes a nutritious, palatable hay. Feeding experiments at a number of experiment stations have shown that Sweet Clover hay, cut at the right time and properly cured, will give equal results with alfalfa hay. There is a little more waste usually with Sweet Clover than alfalfa, but for the pounds consumed, just as good returns in meat or milk production are received.

Sweet clover is usually well adapted for the sandier sections and should be planted rather freely in native pastures. In many places where it is difficult to start alfalfa, or to get a crop of alfalfa, Sweet Clover will make a profitable legume crop in place of it. It can be planted in rows similar to row alfalfa, or planted broadcast. It is sufficiently valuable to be given a thoro trial wherever there is difficulty in growing alfalfa in rows. Probably in those localities where alfalfa does well in rows, it will not be worth while to grow Sweet Clover for hay, but even in such localities it will be well to attempt getting the crop started in pastures. If rightly managed, it will be possible

to materially increase the carrying capacities of many native pastures.

Varieties.—There are three varieties of Sweet Clover that may be encountered. The White Sweet Clover (*Melilotus alba*); the Yellow Sweet Clover (*Melilotus officinalis*); and Small or Annual Sweet Clover (*Melilotus indica*). The two first named varieties are biennial, that is the plants live two years. The third variety is an annual. The Annual Yellow Sweet Clover has no value for pasture or hay as it is very small growing and is less palatable than the other two varieties. For the most of the territory, White Sweet Clover is greatly to be preferred. It is a better hay crop as it grows taller, and stands more erectly. Yellow Sweet Clover does not grow so large and has a more spreading habit of growth. While it is less well adapted for hay, there are some localities where it will do better than the White, notably in extremely high altitudes. In the Platte-Arkansas Divide country at altitudes above 7,500 feet, Yellow Sweet Clover is preferable to the White as it will mature in a shorter season. Yellow Sweet Clover is better for pasture purposes than for hay purposes.

Soil Preparation.—When seeded for a hay crop or when seeded upon old lands, the soil should be prepared exactly as for alfalfa. When seeded in native pastures or in sandy regions among native grasses it can frequently be seeded on the snows in the winter time, or seeded early in the spring and harrowed. Usually this will give sufficient covering to permit the crop to start. Sometimes on land having a rather heavy sod, running over the land with a disk set rather straight, followed with a harrow, is found to be good practice.

Seeding.—Sweet Clover may be seeded in the spring or fall. There is little danger of its being injured by frosts. It can therefore be seeded as early in the spring as the land can be prepared and conveniently worked. Eight to 10 pounds of hulled seed are a great plenty for dry land conditions. Fifteen to 20 pounds of the unhulled seed should be used to make approximately the same stands. Sweet Clover has many so-called hard seeds, which germinate slowly. In this case the "hard seeds" are viable, but the seed coat is impervious to water. Owing to this "hard seed" condition, it is often possible to plant in the fall and get better stands than from spring seeding.

The crop should be given much the same care as alfalfa. The first cutting should not be made until the sprouts which are to produce the following crop commence to appear. Usually one crop can be received the first year if there was sufficient moisture in the seed-bed to properly start the development and maintain the growth thru possible dry spells. The second year two cuttings should be received, except in very drouthy years. The cutter bars should be set high in cutting the second year crop in order not to kill the plants. The plants start out from sprouts which come out on stalks close to the

ground. If cut below these sprouts the crop will be killed. If cut high there will be no danger of this.

Sweet Clover becomes very woody and a bitter principle (*cumerin*) which it contains is very strongly developed as the plant approaches full bloom. Consequently care should be taken to cut the crop as soon as the shoots for the next crop commence to appear. If this is done a more palatable hay of a very much less bitter quality with less waste will be produced.

THE GRAINS FOR HAY

A large use is already being made of many of the grains for both hay and pasture. Winter wheat and rye each make fairly good late fall and summer pasture. These two grains are the only ones at all well adapted for pasture purposes, but they are very well adapted for dry land annual pastures. In the cooler regions, and in the northern and northwestern parts of the Colorado Plains, rye is probably preferable. In the warmer portions, winter wheat will be preferable. Wheat, oats, beardless barleys, rye and emmer will each make a good quality of hay if harvested when the seed is in the milk or soft dough stage. Often these crops will make profitable hay yields, the season taken into consideration, when the grain which is produced upon them would not be worth harvesting.

When grown for hay, these crops are planted and cared for as they would be for grain. For pasture purposes, winter wheat, and rye should be seeded in July; for hay purposes the latter part of September is preferable where the crop is to be harvested the following year. Barley and emmer can be seeded in March if conditions are such that the land can be worked. Oats should not usually be seeded until the middle of April at least, on account of possible injury from late spring frosts. Wheat and rye should be seeded at the rate of about 30 to 35 pounds of seed per acre. Oats should be seeded at the rate of from 40 to 50 pounds; hulless barley should be seeded at the rate of 50 to 60 pounds, and hulled barley at about 60 pounds for hay purposes. Emmer should be seeded at the rate of 60 to 70 pounds. Each of these crops should be seeded with a press drill to obtain best results.

STOCK MELONS

Another source of possible late fall and early winter succulent feed, is Stock Melons. Stock Melons look very much like water-melons, but have a very much thicker rind. Experiments at Eads and Cheyenne Wells show that stock will eat these melons with relish. They make an excellent sod crop and if weeds are kept down will do well on old lands. They are best adapted to the hotter portions of the eastern and southeastern parts of the State. The land should be well prepared, and if sod land, the sod should be rolled flat immediately behind the plow. The melons should be planted in hills at least 10 feet apart each way. On sod land they need very

little cultivation. On old lands they will need sufficient cultivation to keep the weed crop down.

The keeping quality of the melons is good, if kept from freezing. Thus they may be fed out in the fall as desired, if properly protected from being frozen by straw or other covering.

PEAS

Field Peas or Canada Field Peas are exceedingly well adapted to the high lands of the Platte-Arkansas Divide. They are not well adapted to the relatively lower altitudes of the eastern and southeastern parts of the State. It is possible to grow them, but they are not sufficiently profitable to pay for cultivating them under normal conditions except in the Divide territory.

They should be seeded usually on well prepared land at the rate of 30 to 45 pounds per acre, using preferably a disk drill having a revolving cup type of feed in order not to crush the seed. Planting should be done just as early in the spring as weather and soil conditions will permit, as peas develop best in the cool of the year. Peas will do better at an altitude of 6500 to 8500 feet than they will at lower altitudes, because they develop better in the cool weather of the season. It is this feature which makes them adapted to the Divide, and poorly adapted to the other portions of the Colorado Plains.

VETCH

Vetch has been recommended, but in the experimental work carried on thus far it has not given sufficient returns to pay at all. At the present we cannot recommend Vetch for Colorado Plains planting.

PEANUTS

Peanuts is another crop which has been discussed a good deal and recommended by some for our territory. Peanuts is another hot weather crop. In Texas and Oklahoma and other southern States they do exceedingly well, but so far as experiments show, they do not give sufficient promise in our cool climate, with our short growing seasons, to warrant recommending them for much of our territory. They can be grown and occasionally matured as far in the State as Hugo. They do a good deal better in the extreme southeastern part of the State, but even here are not yet well enough adapted to be unqualifiedly recommended.

BROOM CORN

Broom Corn is very well adapted to the southeastern portions of the State and as far west as two tiers of counties from the eastern border. This crop should not be grown in preference to other sorghums for a forage crop, but in some localities Broom Corn is grown for a cash crop. In such localities if the fodder is harvested it will make a very useful and valuable feed. Except to be used in this way it can not be recommended because it is not so valuable as other adapted sorghums as an exclusive forage crop. Where it is grown

for the brush, however, it is worth while to take particular pains to save the fodder which can be dry cured or siloed as circumstances permit.

SOY BEANS

Soy Beans can be grown in the Arkansas Valley from Pueblo eastward. Only the very earliest types, however, are adapted. We have succeeded in maturing some varieties at Cheyenne Wells, but the development of the crop was not such as to warrant recommending it for general planting even in that section. This crop may find a place in the extreme southeastern section, as the season is long enough in that region to permit maturing one or two of the earliest varieties. The Soy Bean is capable of withstanding considerable drouth, so it may find some use in that section.

COW PEAS

Cow Peas is a southern crop. While called Cow Peas, they are in reality not peas at all, but a species of beans. They are killed by the very lightest frosts, consequently they are not adapted to any except the extreme southeastern portions of the Colorado Plains, and even there only one or two of the very earliest varieties can be grown. They do not possess sufficient merit to warrant very general recommendations even for this territory. Both Soy Beans and Cow Peas should be planted in rows and cultivated if their growth is attempted. Such a method takes less seed which is very expensive, and under dry land conditions will give as good or better returns. About 20 pounds of seed will probably be sufficient per acre if planted in rows for cultivation. The seeds are rather large and should be planted with a corn planter or with a grain-drill, stopping part of the holes. The revolving cup type of feed will not break or crack many of the seeds.

PASTURES AND NATIVE HAYS

Russian Thistles.—Russian Thistles are one of the worst weeds of the dry lands. They are much worse pests in dry than in wet years. While they cannot be recommended for purposeful planting, there are occasional seasons when they may be utilized to help a deficient supply of forage. The years of 1911 and 1913 had such seasons.

Russian Thistles when utilized return the most feed when properly siloed. They may also be cut, cured, and stacked for hay. The thistles must be cut before the spines get developed and hard, otherwise there is serious danger to the stock to which the thistle hay is fed.

Native Hays.—Many of the native grasses of the Plains make very nutritious hays. But, except in low places or swales, the growth

is normally insufficient for hay. The Wheat Grasses, Bluestem, and Gramas are the most common native hay species.

Native Pastures.—There are still many places on the Plains where there are large areas of native pasture. Where these native pastures are open range, little may be done to improve their carrying capacity. Where under fence and private control it is possible to very materially improve carrying capacity by letting part of the pasture rest while the other portion is grazed.

Some improvement may often be made by seeding in Sweet Clover. This is especially true of the sandier localities.

In the high Divide country Brome Grass (*Bromus inermis*) does well. Here it may be seeded in the native pastures with a disk drill.



Brome grass grown by Mr. Chas. Green, Leroy, Colorado

The wet valleys in the sand hills often produce Brome quite well. Except under the conditions just mentioned, Brome Grass is very indifferently successful or a total failure.

Tame Pastures.—Tame pastures are among the most serious and difficult problems of dry farming.

No tame grass is ever successful. Brome and Orchard Grass may be grown in the few limited sections above mentioned. But they are not generally adapted. Yet they are the best tame grasses with which experiments have thus far been conducted.

For hog and horse pasture, alfalfa, in rows, may be used. Probably for those animals which may safely be pastured upon it, alfalfa will furnish more feed than any other permanent crop.

Sweet Clover will make some pasture practically anywhere on the Plains, even under conditions too severe for alfalfa.

It may be grazed with greater safety than alfalfa. But it is unsafe to graze Sweet Clover with either cattle or sheep when wet from dew or rain.

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

THE DETHRIDGE METER

By
V. M. CONE, Irrigation Engineer,
U. S. Office of Public Roads and Rural Engineering

This bulletin is based upon work done in the hydraulic laboratory, at Fort Collins, Colorado, under a co-operative agreement between the Colorado Experiment Station and the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture.



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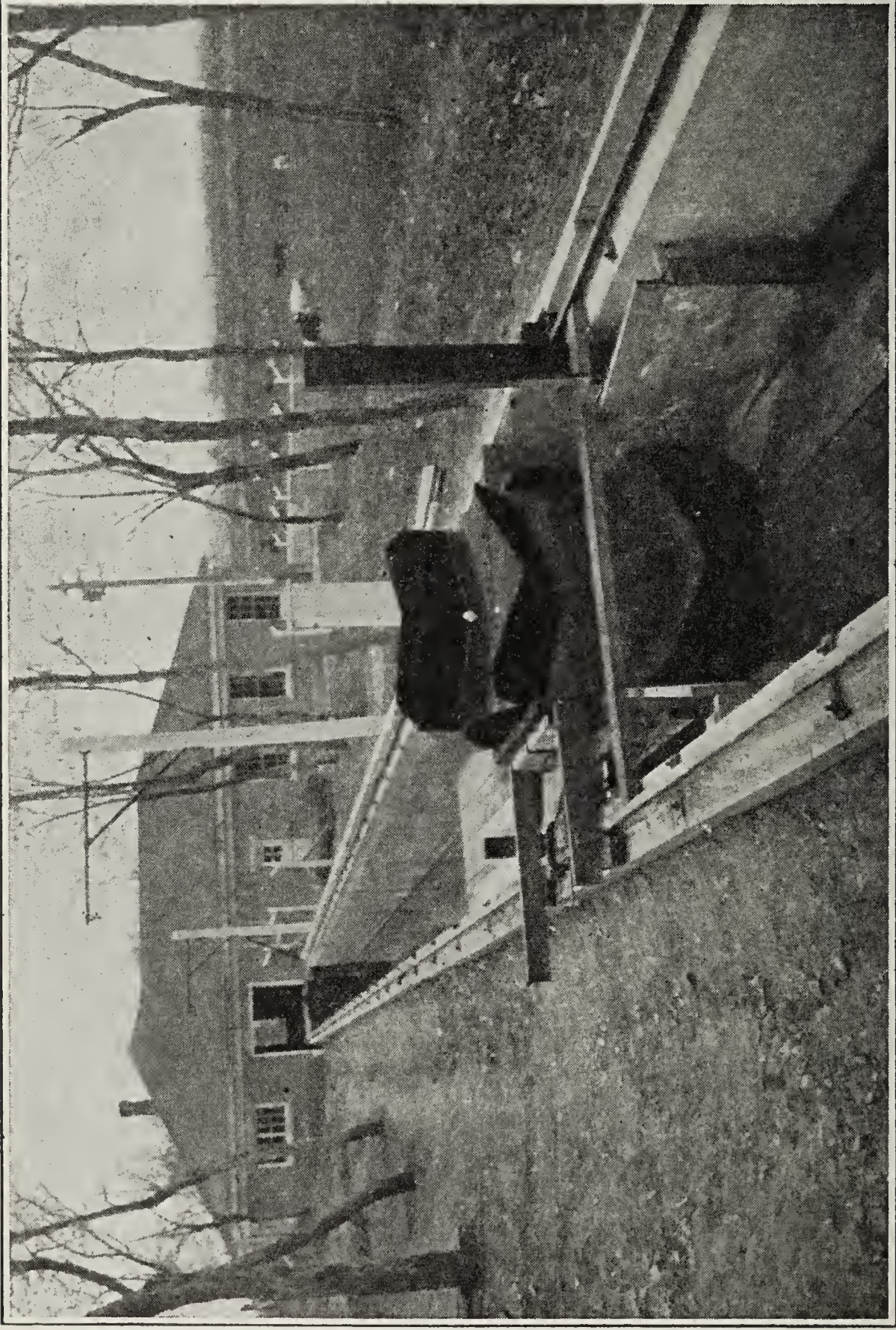
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Dethridge Meter Installed for Testing at Hydraulic Laboratory, Fort Collins, Colorado

THE DETHRIDGE METER

By V. M. Cone, Irrigation Engineer, U. S. Office of Public Roads
and Rural Engineering.

The Dethridge meter is a device for measuring water flowing in open channels. It is the invention of Mr. J. S. Dethridge, member of the State Rivers and Water Supply Commission of Victoria, Australia, and several thousands of them are in use in different parts of Australia for measuring irrigation water. At the present time few are in use in the United States, except for experimental purposes. In Australia, but one size of meter, the 5-foot wheel, is used, and where it is necessary to measure the flow in a ditch in excess of the capacity of a single meter, two or more wheels are placed side by side with walls between them to divide the flow.

For the purpose of better adapting the Dethridge meter to irrigation conditions in the United States, three sizes of wheels, with no essential changes in Mr. Dethridge's design, were experimented with at the hydraulic laboratory at Fort Collins, Colo., during the summer of 1915. The statements in this bulletin are based on these experiments.*

The meter consists of a drum with projecting vanes so placed in the box or structure in the ditch that there is a uniform clearance of from one-fourth to three-eighths inch between the walls of the box and sides of the wheel, and also between the vanes and the curved floor of the box. Spokes made of 2x4 lumber are placed inside the drum; one set of spokes in each end of the drum for the smaller sizes, and a third set in the middle for the largest sized drum.

A horizontal shaft made of one-inch pipe is placed through the spokes at the center of the drum and this shaft is supported in a horizontal position by 4x4 wood block bearings. A bearing made by boring a hole in a 4x4 block of wood is durable and entirely satisfactory if oiled occasionally. A large nail placed through a hole bored in the pipe shaft and stapled to one of the spokes will prevent the wheel from turning on the shaft. It may be necessary

*Other experiments with this meter have been made by the Office of Experiment Stations in co-operation with the University of California at Davis, Cal., the results being published in California University Agricultural Experiment Station bulletin 247.

to place a washer on each side of the wheel between the spokes and the wall, to prevent the wheel from rubbing the sides.

A cyclometer or bicycle counter made of rust resistant metal, which may be purchased for \$1.00 or less, is fixed in a recess in the side of the wall near one end of the shaft as shown in Fig. 1. A sixteen penny nail placed through a hole drilled in the shaft about a quarter of an inch from the end of the shaft, serves as a pin to turn the counter. Injury to or interference with the counter is

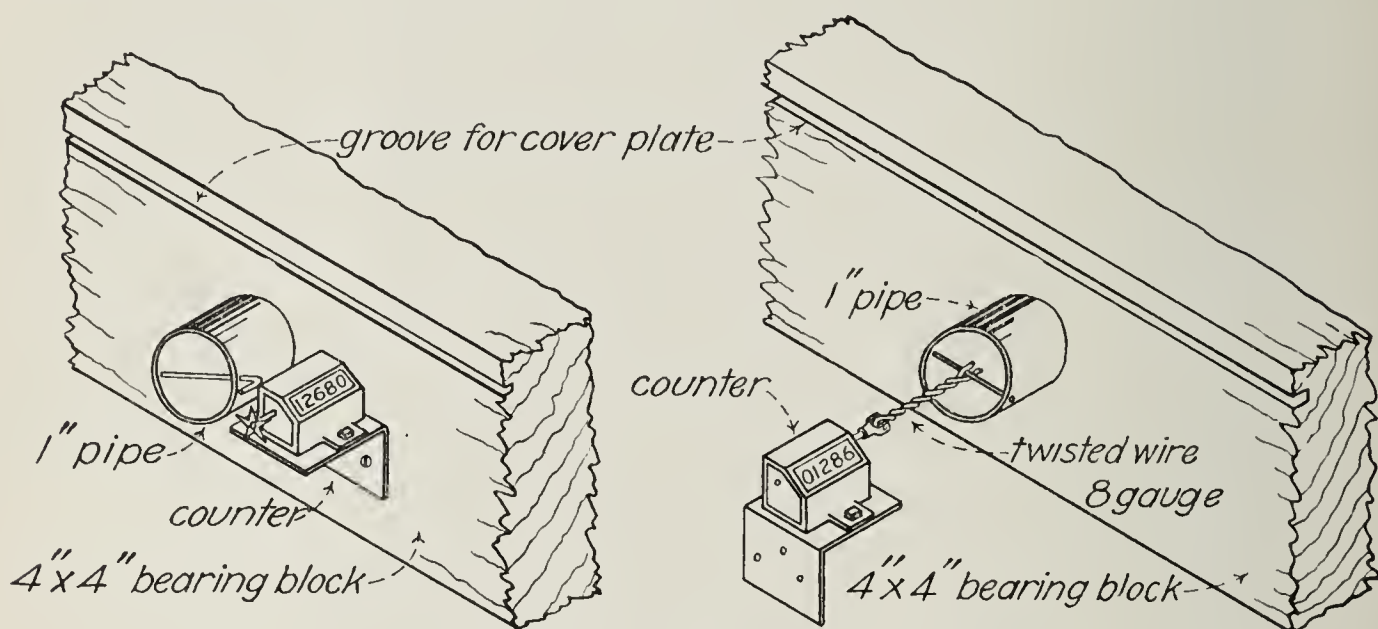


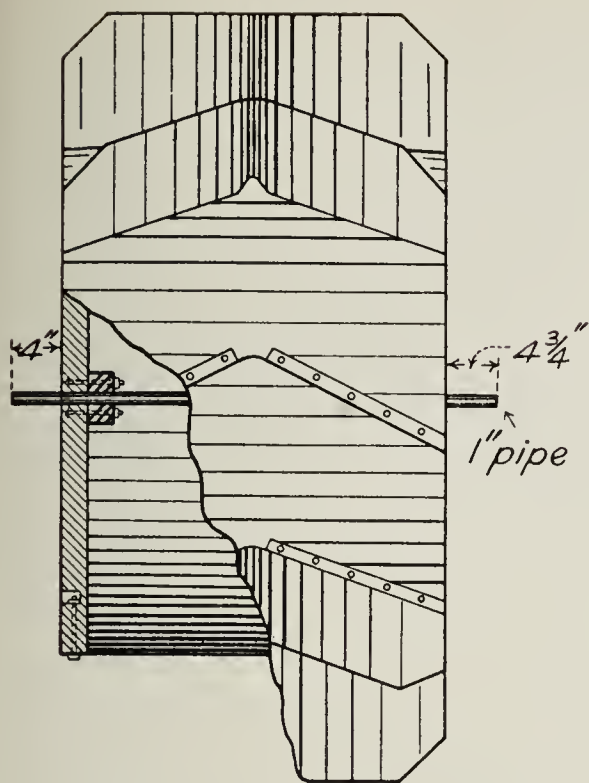
Figure 1. Arrangement of Counter on Dethridge Meter.

prevented by a sheet metal plate, one edge of which is set in a groove in the bearing block, and the other edge is held by a staple and padlock.

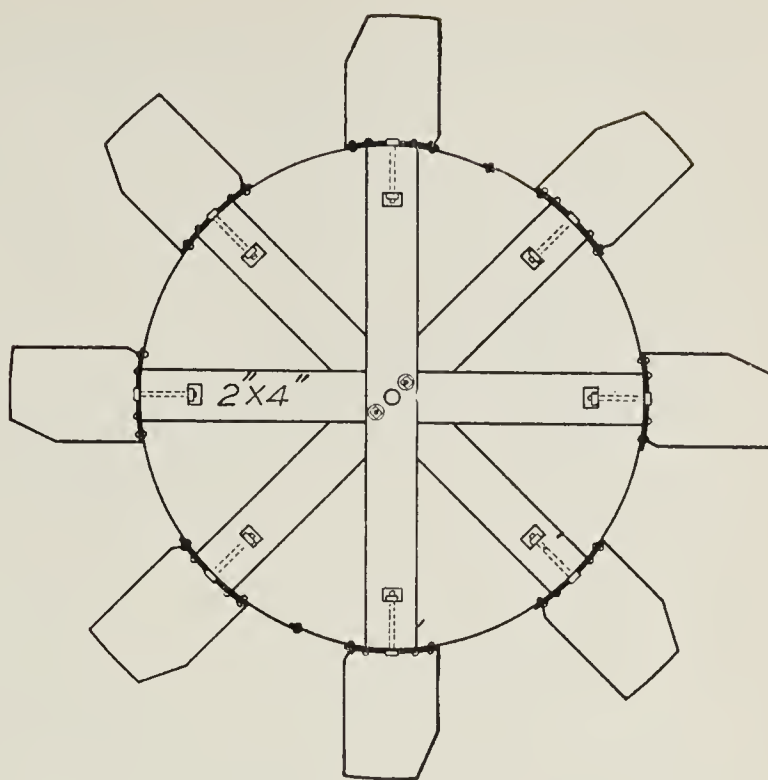
The sheet metal work on the wheel, Fig. 2, is not especially difficult, but it should be made in a shop where the necessary machinery is at hand. The cost of the wheels used in these experiments was \$23, \$25 and \$27.50 for the 4, 5 and 6-foot diameters respectively. These costs were for the wheels complete with axles, and as they were made largely by hand, it is certain that the prices could be lowered from \$5 to \$10 if made in lots of twenty or more.

The box or structure which contains the wheel, Fig. 3, may be made of wood or concrete. Concrete is to be preferred where practicable, for it insures the proper clearance being maintained between the wheel and the box. It is the practice in Australia to make the box of concrete sections, which are cast in a central place, seasoned, and cemented together after being hauled into the field where wanted.

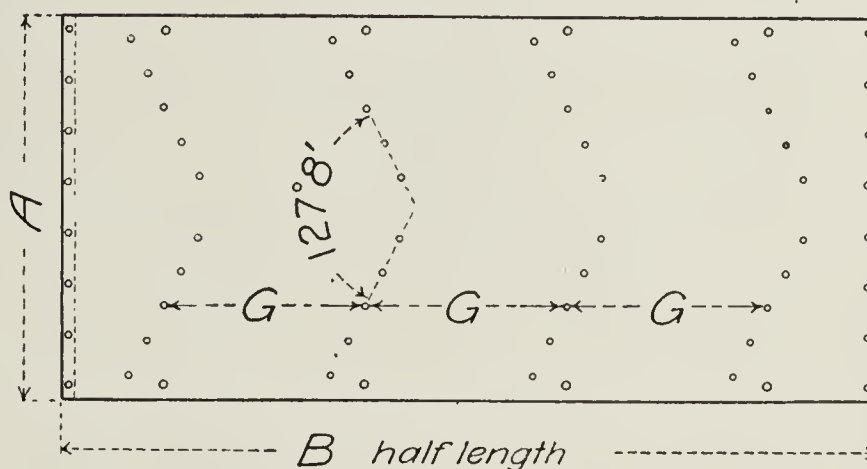
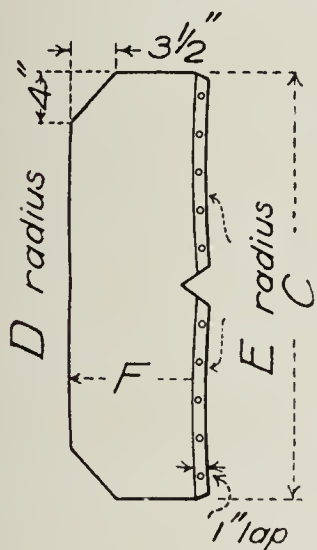
The Dethridge meter has many points of advantage. It is simple, easily understood, records the flow under varying conditions, requires little loss of grade for operation within its normal



Elevation and Section



End Elevation



Development of Vane and Drum Sheets
Figure 2. Details of Wheel for Dethridge Meter.

capacity, is free from sand and silt trouble, and has no delicate working parts. Its one principle disadvantage is that any large piece of floating trash, such as a Russian thistle, will be liable to clog the wheel, and result in damage by causing the water to top the ditch bank. Blocks of wood or other floating trash may float into the space between the blades and the drum, and be carried under without damage, but if the trash is caught by the edge of the vane, it will be carried down and wedge on the floor.

The wheel may be lifted to allow the ditch to be cleared of trash when water is first turned in each season. It is advisable to place a Dethridge meter not far from the headgate, for this offers the least liability of trash being collected in the ditch, with resulting interference with the operation of the wheel.

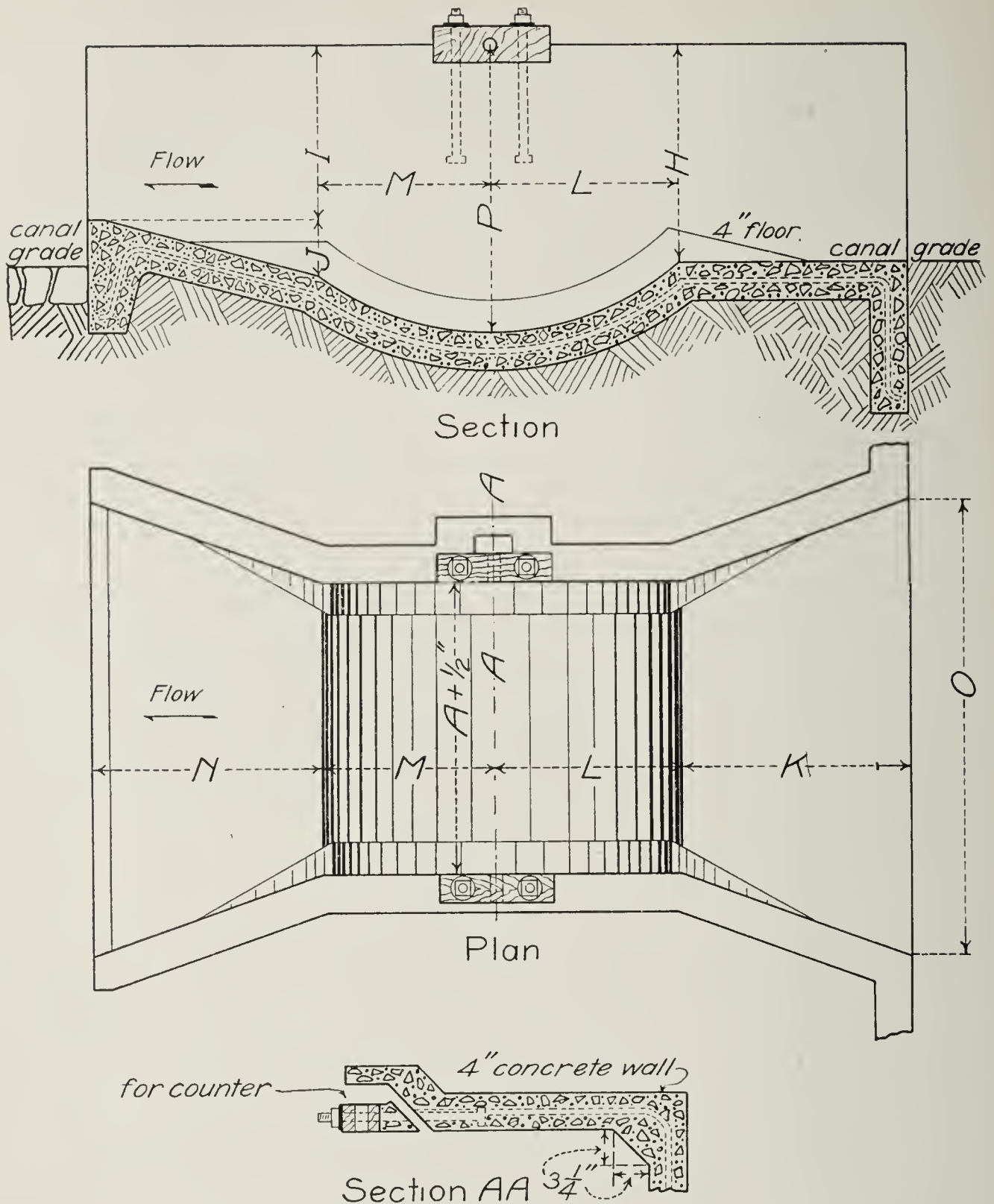


Figure 3. Details of Box for Dethridge Meter.

The speed of the wheel varies with the flow of water in the ditch. If the wheel should fit the structure so as to leave practically no clearance, except to allow a free motion of the wheel, each revolution would deliver exactly the same volume of water regardless of the speed of the wheel or depth of the water in the ditch. The clearance of one-fourth of an inch allows some water to slip by, and this slippage changes with the depth of water in the ditch, and the difference in the depth on the upstream and downstream sides of the wheel. The actual volume which passes the wheel is therefore greater than the volume required to fill the space between the vanes and the drum, and the curves shown in the accompanying

TABLE 1—DIMENSIONS OF DETHRIDGE METERS.
(Letters Refer to Figs. 2 and 3.)

	—4 Feet—			—5 Feet—			—6 Feet—		
A.....	2'	0	"	2'	6	"	3'	6	"
B.....	4'	3	$\frac{1}{4}$ "	5'	3	$\frac{3}{4}$ "	6'	4	$\frac{3}{8}$ "
C.....	2'	2	$\frac{3}{4}$ "	2'	9	$\frac{1}{2}$ "	3'	10	$\frac{7}{8}$ "
D.....	10'	0	"	12'	8	"	15'	0	"
E.....	6'	8	"	8'	5	"	10'	0	"
F.....		8	"		10	"		12	"
G.....	1'	0	$\frac{9}{16}$ "	1'	3	$\frac{11}{16}$ "	1'	6	$\frac{7}{8}$ "
H.....	1'	7	"	1'	11	"	2'	3	"
I.....	1'	3	"	1'	6	"	1'	8	"
J.....		4	"		6	"		9	"
K.....	2'	8	"	2'	0	"	3'	0	"
L.....	1'	2	$\frac{3}{4}$ "	1'	7	$\frac{1}{2}$ "	2'	1	"
M.....	1'	1	$\frac{1}{4}$ "	1'	6	$\frac{1}{2}$ "	1'	10	$\frac{1}{4}$ "
N.....	2'	6	"	2'	0	"	3'	0	"
O.....	4'	0	"	4'	0	"	5'	6	"
P.....	2'	0	$\frac{1}{4}$ "	2'	6	$\frac{1}{4}$ "	3'	0	$\frac{1}{4}$ "
*.....	2'	9	"	3'	3	"	4'	3	"

*Length of 1-inch pipe for axle.

diagrams represent the average condition. The irregularity of the points in Fig. 4 plotted from the experimental values is not due to error, but is due to changed conditions of flow in the ditch during the several experiments.

Experiments were made to determine the effect of various changes in the shape of the box. The uprising lip of the floor was eliminated and the wheel was set lower in the ditch to give the same submergence of the vanes, but this change resulted in no advantage whatever. It interfered with the flow of the water, and decreased the capacity of the wheel as much as 20 per cent.

The normal capacities of the 4, 5 and 6 foot diameter wheels are $\frac{3}{4}$ to $2\frac{1}{2}$ second feet, 1 to 4 second feet and 1 to 8 second feet respectively. They may carry an additional 1 or 2 second feet, but there is a greater loss of head, and the force of the blades is such as to splash water over the sides of the box. It also results in excessive washing of the banks below the box. The wave action caused by the wheel under normal operation requires some bank protection below the box.

The principle value of the Dethridge meter is that it integrates or adds up all the water that is passed through the meter, regardless of any changes that may have occurred in the rate of flow, and it also keeps a record of the total amount. It is therefore, a total flow meter, but may also be used to indicate the quantity flowing at any certain time.

To determine the quantity of water flowing through the meter at any time, count the number of revolutions of the wheel in one

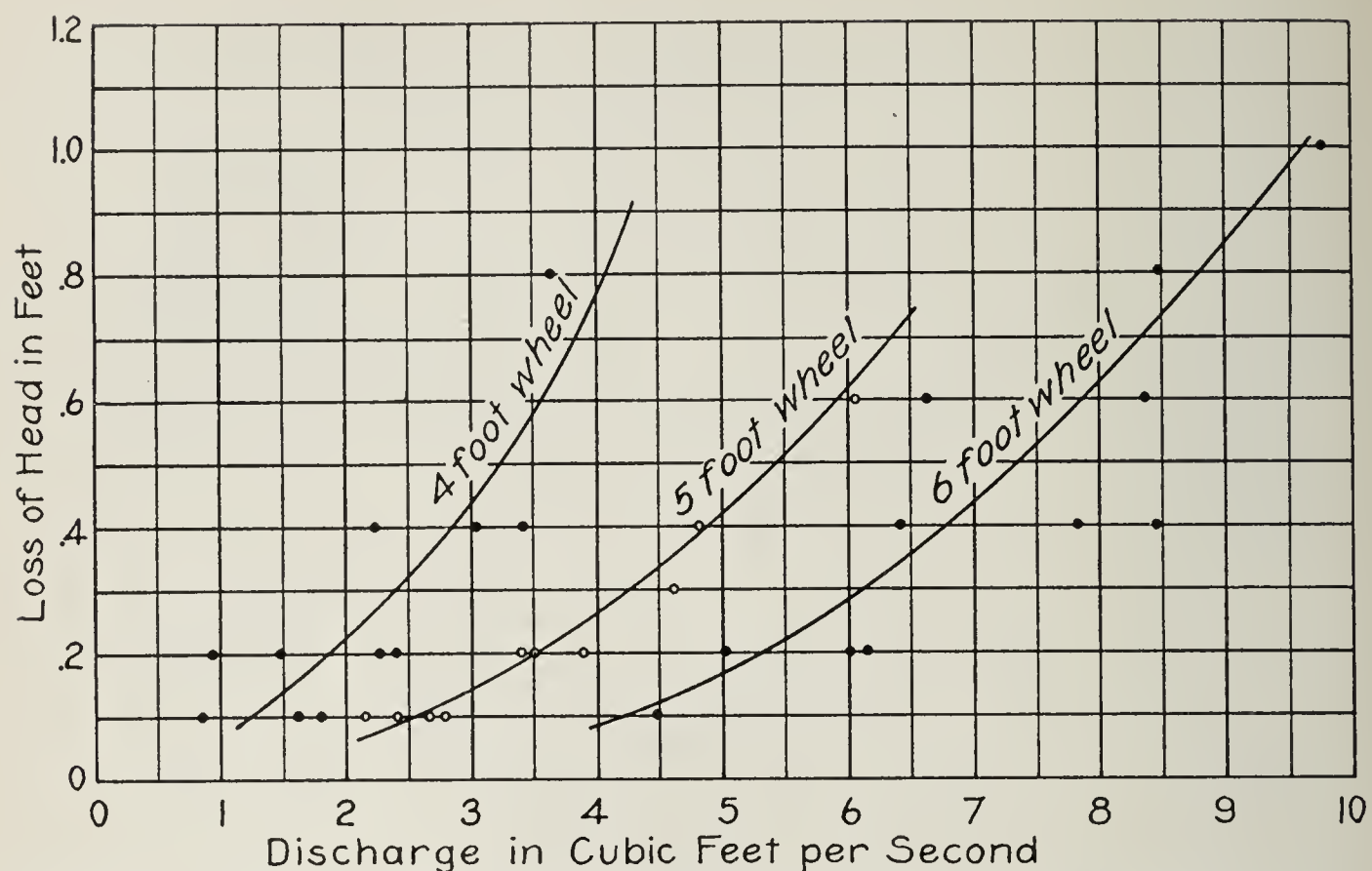


Figure 4. Loss of Head for Different Flows Through Dethridge Meter.

minute, locate this number on the vertical scale in Fig. 5, follow along this line to the right until the curve is reached for the size of wheel used, then follow straight downward to the bottom line where the discharge in second feet will be found. For example, 9.5

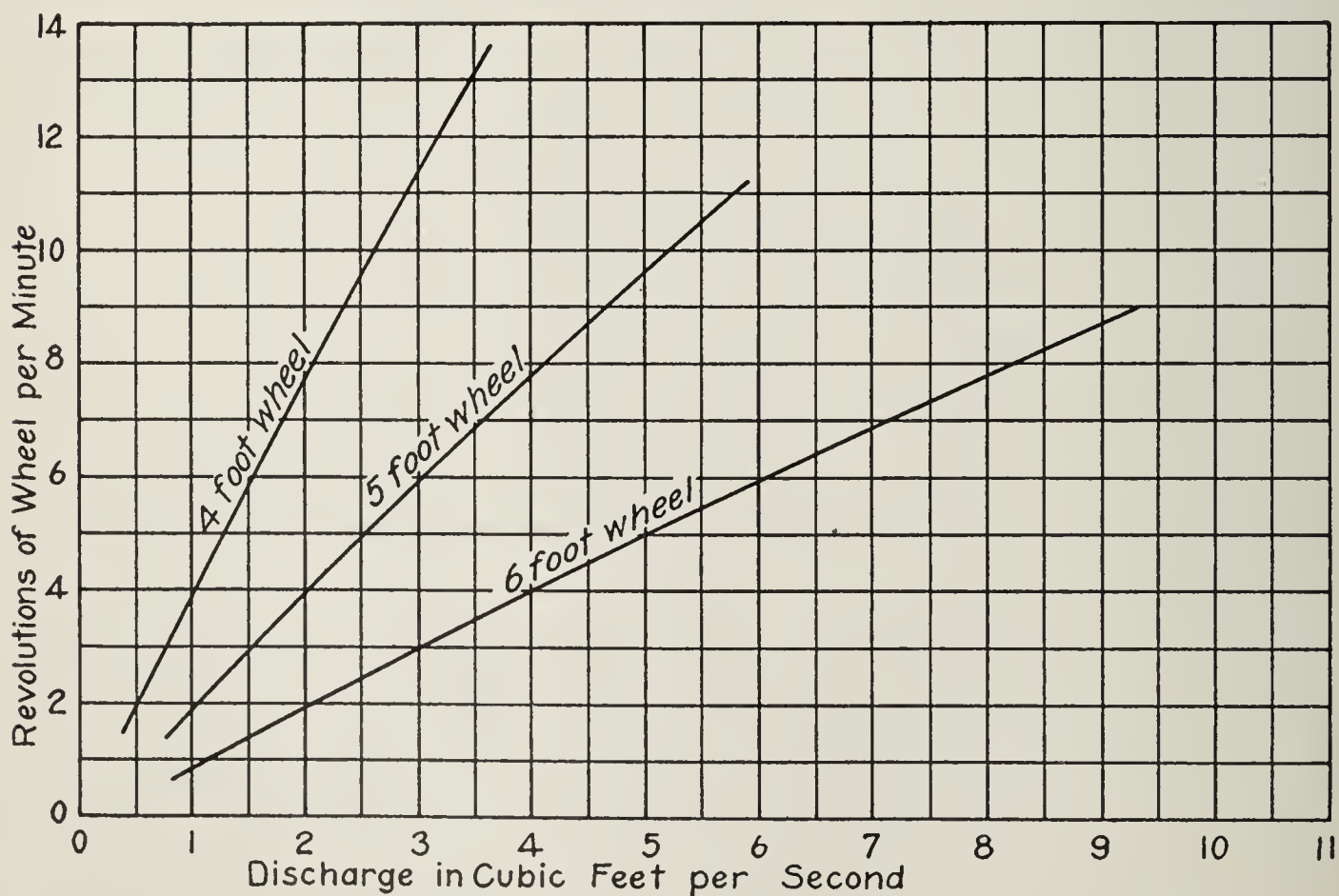


Figure 5. Water Passing Dethridge Meter with Wheel Turning at Different Speeds.

revolutions per minute for a 4 foot wheel gives a discharge of 2.5 second feet.

Fig. 4 shows the approximate loss of head or drop of water surface which will be necessary to allow different quantities of water to flow through the meter. These curves are of use in deciding what size of wheel to install to meet any certain ditch condition.

To determine the total quantity which has flowed through the meter during any certain period of time, take the difference between the counter readings at the beginning and termination of this period, and multiply this difference by the fraction of an acre inch of water delivered by each revolution of the wheel, as shown in Fig. 6. For example, if the counter reading at the start is 21695 and at the stop is 23825, the wheel made 2,130 revolutions. If the wheel is 6 feet

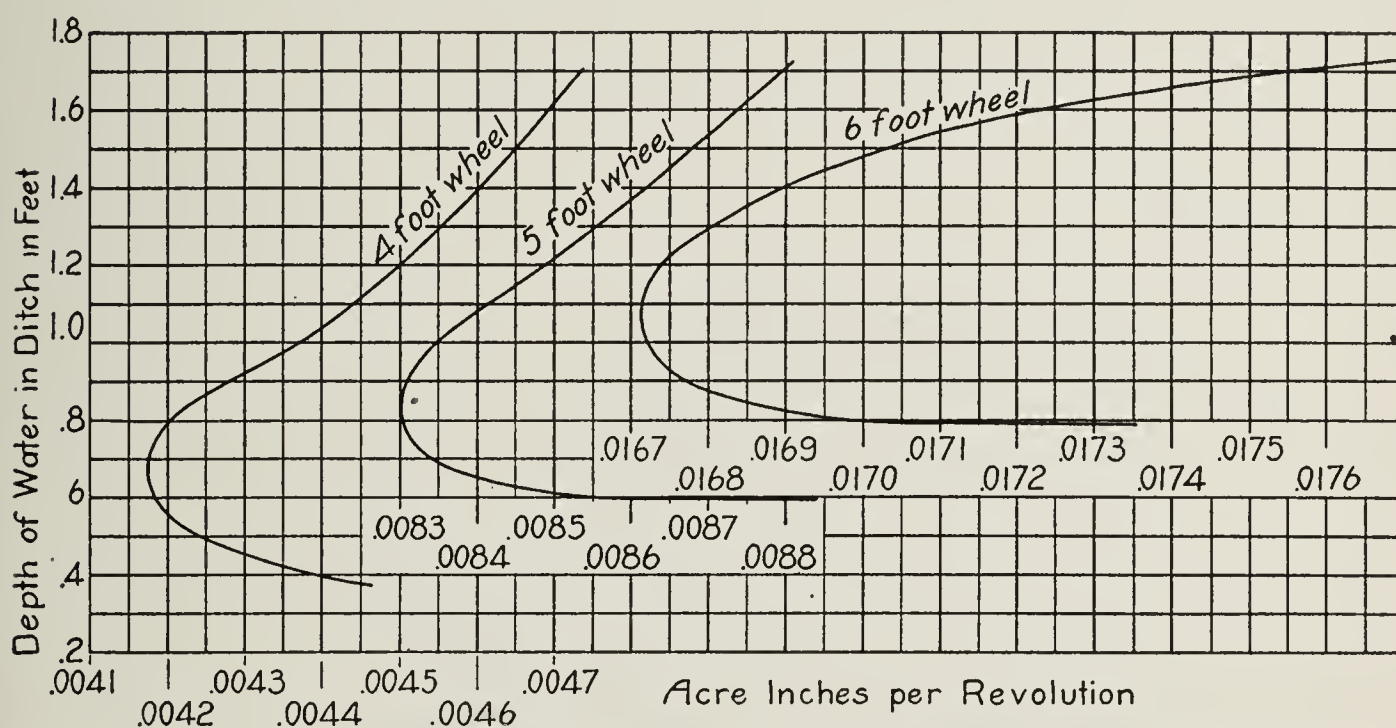


Figure 6. Rating Curve for Dethridge Meters. For Converting Revolutions of Meter into Acre Inches of Water Delivered.

in diameter and the average depth of water in the ditch upstream from the wheel was 1.4 feet, it will be seen in Fig. 6 that each revolution of the wheel has delivered .0169 acre inches of water. Multiply 2130 by .0169 and the result is 36 acre inches or three acre feet of water. If six acres were irrigated, the land was covered to an average depth of 6 inches.

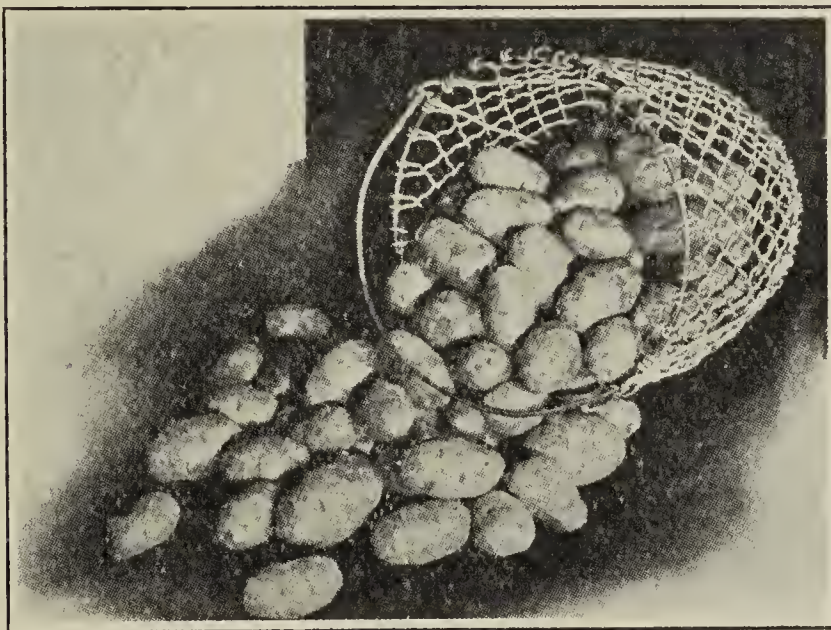
It is necessary that the wheel and box of the Dethridge meter, as well as the clearance between the vanes and the box, be the same as given in the accompanying plans, if the rating curves given in Fig. 6 are to be used. Under ordinary conditions of canal operation a Dethridge meter should register the flow with an error not exceeding 2 per cent, and even under unusual ditch conditions, but with proper construction of the meter, the error should not exceed 5 per cent.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

STUDIES OF HEALTH IN POTATOES



By C. L. FITCH

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
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*Now connected with Extension Department of Iowa State College. The Colorado data used in this bulletin was collected by Mr. Fitch during the years 1910 to 1912. Because of a lack of funds it has been impossible to publish the bulletin until this time.

STUDIES OF HEALTH IN POTATOES

By C. L. FITCH

In July and August of 1911 it became apparent that every potato plant in the fields attacked, and nearly every field in two of the great potato-producing regions of Colorado, had been crippled by the leaf-roll disease. One of these regions was on the plains and subject to very warm and continuous sunshine. The growers of the other district had been purchasing most of their seed potatoes from the first region and their potato fields were subject to considerable soakage, due to their system of irrigating by filling the subsoil with water to such a level that the roots were supplied with moisture by capilarity. At the same time the crops of potatoes on the mountain mesas throughout the State, even when grown from the same seed, were excellent.

The growers in the first region, the Greeley district, had been unable for years to grow their own seed potatoes for more than one or two propagations and had drawn upon unirrigated regions for their foundation seed supply. For a considerable number of years it had been increasingly difficult to produce tubers of the most desirable shape. While formerly, the second crop of potatoes had been the better because of the improved condition of the soil, at this time the second crop had become very much poorer in quality and less in quantity, and that, in spite of increasing average yields of grain upon the same fields.

In the second region, the San Luis Valley, seed stocks had been maintained more easily, but better results had been secured from small whole potatoes such as were readily obtained from the Greeley district, and of late years the Valley had used such seed for most of its potato fields.

A careful study, at the weather bureau in Denver, of the temperatures throughout the year, and other years, for the stations nearest to afflicted and to healthy potato regions, and of the rainfall, lead to the belief that the factors controlling the appearance of the leaf-roll disease were none other than soil-heat and soakage. Where the fields had been unusually warm and wet the disease had come; where the soil had been cool and not over-wet the plants had been healthy.

A careful field study of potato roots during midsummer revealed the fact that in the warmer regions the roots within six inches

of the surface were badly diseased as compared to those deeper in the soil. This field study of roots was supplemented later by a study of the root cap and by a study of the potato leaf and its adaptation to an arid climate. It was decided later to study in detail the effect of soil-temperature and soakage upon potato plants grown during the winter of 1911 and 1912 in the College greenhouse (Figure 1).

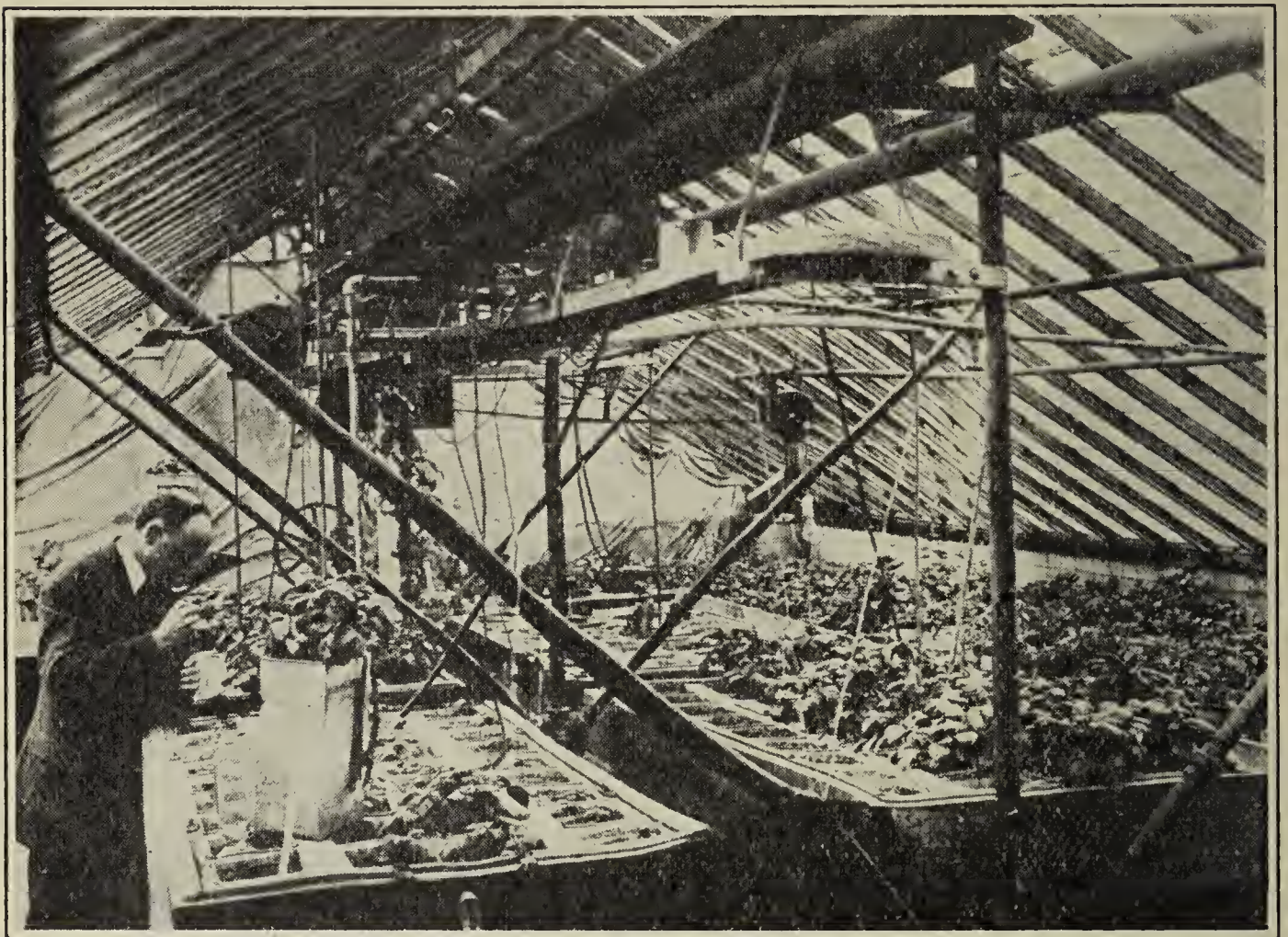


Figure 1.—Greenhouse experiment to determine effect of soil temperature and soakage upon the potato plant.

Careful study was given to the history and practices of the various potato-growing districts, and field evidence was secured which seems to the writer conclusive that the leaf-roll disease in Colorado had, in addition to these causes—soil-heat and soakage—a third cause, probably parasitic and in some way injurious and capable of distribution.

Out of these studies, and out of field studies made later over Iowa, an attempt is made in the summary to make somewhat clearer the essential conditions for health in potatoes and for permanency in potato production. More space is given to detailed reports of observation and experiments, but what may be called evidence-in-

the-large is regarded as of most value. These studies will be presented under the following heads:

- I. Studies of soil temperatures.
- II. Studies of potato roots and the potato leaf.
- III. Greenhouse studies of the effect of various soil temperatures and percentages of moisture upon potato plants.
- IV. Field studies of heat and soakage, and temperatures of soil and of irrigation water.
- V. History and practices of potato-growing districts.
- VI. The hope and the great difficulty of attempting to secure disease-resistant potatoes.
- VII. Summary of what we know of the conditions for potato health and permanent potato production.

I. STUDIES OF SOIL TEMPERATURES.

It was desired to know whether soil temperatures vary greatly in different seasons. The Colorado Station at that time had no soil temperature records but we had recourse to the very complete records kept by the Nebraska Station, and selected for comparison with each other the temperatures at Lincoln for known good years and known years of poor production. Certain of these are summarized below:

MEAN SOIL TEMPERATURES AT DIFFERENT DEPTHS.

(Taken at the Agricultural Experiment Station, at Lincoln, Nebraska, for May, June, July, and August of 1894 and 1901, dry hot years, and for the same months of 1897 and 1902, years of average weather and good moisture supply.)

	1 inch	3 inches	6 inches	9 inches	12 inches	24 inches	36 inches
1894							
(Dry year)							
May	63.3	72.7	68.6	66.8	64.7	59.2	59.0
June	73.4	40.1	75.6	73.7	71.5	65.7	62.6
July	86.9	87.6	82.2	80.0	77.9	72.5	68.8
August	88.7	89.2	83.0	81.1	79.8	75.3	72.2
1897							
(Good year)							
May	65.9	62.4		61.1	57.7	54.4	52.3
June	76.9	69.7		71.1	65.9	61.5	58.6
July	86.6	82.8		81.1	74.7	68.7	66.2
August	84.4	80.5		79.3	73.9	70.7	68.7
1901							
(Dry year)							
May	76.3	75.4	71.6	66.8	62.4	56.6	53.2
June	89.6	88.5	84.0	77.6	72.5	65.1	60.8
July	107.3	102.2	95.3	87.3	81.9	74.1	69.3
August	94.0	92.2	88.4	82.3	78.4	73.7	70.9
1902							
(Good year)							
May	75.2	74.6	71.9	67.4	63.4	57.6	54.5
June	75.3	74.3	72.4	70.2	67.4	63.7	61.5
July	82.0	81.8	78.6	75.6	73.2	68.7	66.1
August	79.1	79.3	77.8	74.8	73.1	70.8	68.9

The above records are sufficient to show that drouth is not the only injurious factor in the dry years but that soil temperature may reach an injurious point in such years. If the temperature for July

of 1901 and 1902 be compared, a great difference is seen. Those for 1901 would be dangerous to all potato roots in the entire upper foot of soil.

Keen observers among the farmers at Greeley were of the opinion that the great injury to the potato crop in 1911 had come during the extreme heat of the month of June. On inquiry, Mr. Max Mendelssohn, agricultural and chemical expert of the Great Western Sugar Company, told us that when he first came to the arid country from Germany, he had realized that a high soil temperature was one of the things to be contended with in beet sugar production. The writer was so fortunate as to secure from Mr. Mendelssohn's associate, Mr. Asa C. Maxson, soil temperatures at Longmont, close to the Greeley district, for 1911 and for the previous year, 1910, a favorable year for potatoes. These temperatures are given below and taken in connection with the Nebraska figures, show conclusively that the whole of the upper foot of soil may be as much as ten degrees warmer one year than another for the whole of the critical month of June, and that, as a matter of fact, such was the case in 1911 as compared to 1910. They show, also, that the cooler years, with more rain and cloudiness and less continuous and intense sunshine, are freer from the extremes of soil temperatures that do the injury. June is the month, in the Greeley district, when potato roots are growing rapidly in the upper foot of soil and when the leaves do not, as yet, afford much shade to the soil.

SOIL TEMPERATURES AT LONGMONT, COLORADO, 1910, TAKEN BY
ASA C. MAXSON.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
June 1.....	61	81	58	75
June 2.....	72	82	64	69
June 3.....	41	50	50	63
June 4.....	49	82	57	68
June 5.....	51	71	57	66
June 6.....	59	69	51	64
June 7.....	59	90	52	73
June 8.....	72	87	61	76
June 9.....	64	86	54	77
June 10.....	63	80	55	73
June 11.....	58	94	55	81
June 12.....	60	74	59	68
June 13.....	64	65	57	63
June 14.....	59	90	54	72
June 15.....	70	82	63	74
June 16.....	69	69	64	68
June 17.....	68	82	58	73
June 18.....	71	99	64	85
June 19.....	76	106	69	85
June 20.....	70	90	66	80

STUDIES OF HEALTH IN POTATOES.

7

SOIL TEMPERATURES AT LONGMONT, COLORADO, 1910—Continued.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
June 21.....	70	91	67	86
June 22.....	69	84	68	81
June 23.....	73	92	68	63
June 24.....	69	67	69	69
June 25.....	59	87	66	77
June 26.....	64	97	70	85
June 27.....	67	91	64	86
June 28.....	68	82	66	81
June 29.....	68	82	65	79
June 30.....	59	77	61	71
Averages	64	83	61	70
July 1	66	82	64	79
July 2	68	77	62	84
July 3	66	84	67	81
July 4	72	77	73	82
July 5	73	77	68	77
July 6	69	95	65	86
July 7	82	100	75	90
July 8	73	104	68	88
July 9	68	72	69	70
July 10	64	81	64	76
July 11	64	82	74	77
July 12	64	79	63	80
July 13	63	75	63	76
July 14	73	108	68	89
July 15	76	106	72	91
July 16	73	92	70	86
July 17	73	101	73	88
July 18	77	98	72	88
July 19	79	86	77	86
July 20	73	86	74	82
July 21	75	93	73	88
July 22	72	90	73	86
July 23	75	106	75	95
July 24	72	97	76	93
July 25	72	105	73	93
July 26	72	99	73	94
July 27	83	77	77	85
July 28	59	68	73	77
July 29	59	59	68	68
July 30	61	83	62	73
July 31	72	99	62	82
Averages	71	88	70	83.5
August 1	73	90	70	85
August 2	77	88	68	81
August 3	72	102	68	87
August 4	68	59	68	72
August 5	58	56	69	70
August 6	61	86	62	79

COLORADO EXPERIMENT STATION.

SOIL TEMPERATURES AT LONGMONT, COLORADO, 1910—Continued.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
August 7	59	81	59	75
August 8	63	73	63	72
August 9	54	86	59	73
August 10	63	77	59	77
August 11	70	82	68	75
August 12	68	81	68	79
August 13	68	81	63	73
August 14	64	86	59	73
August 15	68	91	61	78
August 16	59	76	60	74
August 17	60	63	61	64
August 18	49	91	59	79
August 19	68	86	63	79
August 20	75	82	68	77
August 21	79	38	63	79
August 22	75	88	68	72
August 23	72	73	68	77
August 24	64	68	64	75
August 25	52	75	58	70
August 26	50	97	54	76
August 27	70	102	68	95
August 28	59	100	59	95
August 29	61	93	70	97
August 30	59	73	61	72
August 31	54	86	59	73
Averages	64	83	64	78

SOIL TEMPERATURES AT LONGMONT, COLORADO, 1911. TAKEN BY
ASA C. MAXSON.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
June 1	62	81	67	73
June 2	66	81	64	79
June 3	72	90	70	82
June 4	79	88	72	83
June 5	75	90	72	86
June 6	77	90	73	84
June 7	81	84	70	84
June 8	79	94	72	86
June 9	75	94	70	86
June 10	81	97	71	88
June 11	83	104	74	90
June 12	83	97	75	90
June 13	83	97	75	88
June 14	81	89	67	82
June 15	74	74	77	74
June 16	72	84	68	77
June 17	77	93	68	85
June 18	77	91	71	86
June 19	81	95	73	88

SOIL TEMPERATURES AT LONGMONT, COLORADO, 1911—Continued.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
June 20.....	77	82	76	80
June 21.....	84	86	71	81
June 22.....	82	95	70	86
June 23.....	81	97	73	88
June 24.....	84	89	75	83
June 25.....	74	90	72	75
June 26.....	..	..	73	87
June 27.....	79	89	75	89
June 28.....	79	95	78	86
June 29.....	81	95	77	84
June 30.....	77	96	76	90
	—	—	—	—
Averages	78	94	72	84
July 1	72	82	70	77
July 2	..	84	..	83
July 3	75	89	68	83
July 4	82	88	73	83
July 5	77	84	72	80
July 6	77	92	72	83
July 7	83	88	74	84
July 8	70	97	70	84
July 9	70	97	70	84
July 10	81	97	72	86
July 11	82	97	75	88
July 12	83	98	77	90
July 13	82	91	79	87
July 14	84	101	77	91
July 15	83	85	78	84
July 16	77	86	72	80
July 17	75	98	71	88
July 18	79	80	75	80
July 19	73	79	71	75
July 20	74	98	69	87
July 21	79	92	75	86
July 22	83	92	76	87
July 23	77	95	..	..
July 24	73	88	73	82
July 25	77	..	72	..
July 26	80	97	76	88
July 27	83	92	76	89
July 28	81	92	76	87
July 29	83	98	75	90
July 30	82	95	77	89
July 31	82	91	74	87
	—	—	—	—
Averages	79	90	74	85
August 1	81	92	75	87
August 2	80	88	76	83
August 3	77	93	73	86
August 4	75	89	74	84

SOIL TEMPERATURES AT LONGMONT, COLORADO, 1911—Continued.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
August 5	79	95	74	85
August 6	78	95	76	88
August 7	88	99	77	90
August 8	84	101	77	90
August 9	84	94	78	85
August 10	83	85	78	83
August 11	79	91	74	84
August 12	80	92	74	88
August 13	80	94	75	88
August 14	80	99	76	90
August 15	86	94	77	91
August 16	80	83	77	82
August 17	..	..	..	..
August 18	..	..	..	..
August 19	..	..	..	..
August 20	..	..	..	..
August 21	..	..	..	..
August 22	73	81	73	79
August 23	73	87	71	81
August 24	71	74	71	75
August 25	70	90	66	81
August 26	75	88	69	82
August 27	73	81	72	77
August 28	75	89	69	81
August 29	74	86	70	82
August 30	76	95	71	86
August 31	77	90	72	85
Averages	78	89	74	83

II. STUDIES OF POTATO ROOTS AND THE POTATO LEAF.

During the seasons of 1911 and 1912 field studies of potato roots were made at Del Norte, Carbondale, Kersey, Greeley, Fort Morgan and in a dry land district at Haxtum. Holes about 3x10 feet were dug across two rows of potatoes and deeper than potato roots were found, the latter being identified when very small by the taste. The accompanying diagram (Figure 2) illustrates the root habits determined by these studies.

Potato roots in open, well-drained, sandy loams go to a considerable depth, limited apparently by the size of the plant, and extending as much as four feet below the seed piece. In the case of Peach-blows the distance *S* to *B* is often as much as five feet. Early Ohios, under the same conditions, go down not to exceed three feet and to the side not to exceed four feet. We found that deep cultiva-

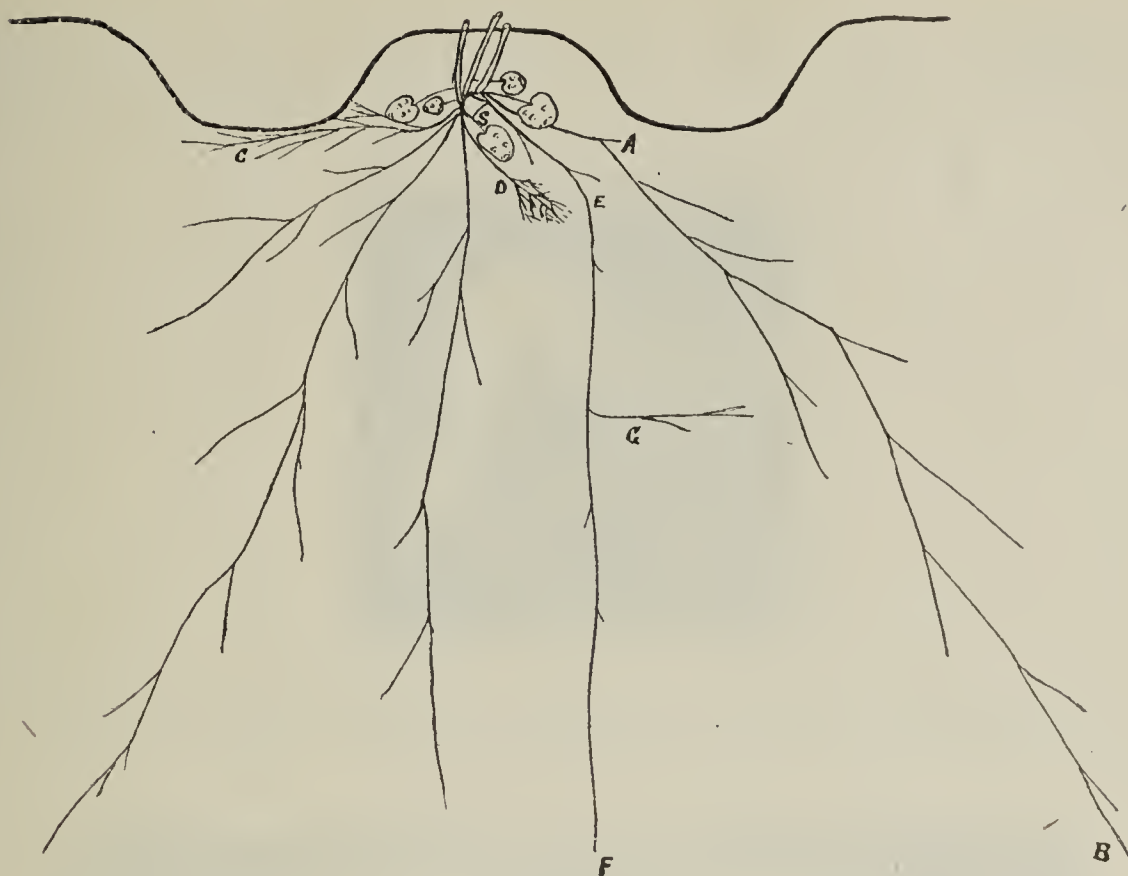


Figure 2.—Diagram illustrating the root habits of potatoes.

tion tends to deeper root growth. A root cut off as at *A* tends to develop branches running deeper. A specially rich spot of earth, or composted manure, stimulates an abundant feeding-root system, as at *D*. After the leaves shade the entire ground and the weather becomes cooler the surface soil is filled with fibrous roots, as shown at *C*. For a full crop, it is important that this richest soil be completely utilized at the end of the growing season. Crops that do poorly early in the season have the least chance to make good because they do not shade the ground as well.

In relation to other roots, particularly those of sagebrush and alfalfa, we found that potato roots seem to gain nothing from the other roots while they are alive, nor before they decay. In recently plowed alfalfa land the soil is more tightly packed about the roots than elsewhere. Potato roots do not go down the alfalfa roots the first year, but the second year the alfalfa roots furnish both food, air and space, and when a potato root reaches a decayed alfalfa root, as at *E*, it goes on down for several feet, as to *F*, and even through soil which the potato root alone would not enter. If, in such heavy soil, there are sandy layers the potato roots enter them as at *G*.

On the dry land we found potato roots stopped by a dry subsoil. The season of 1911 was one of scant moisture and at the time of the studies in 1912 the subsoil, though loamy, was so dry that the potato roots did not enter it, but were confined to the upper two feet, moistened by the rains of 1912. At Carbondale and Kersey we found potato roots stopped by clay. On the E. E. Edgerton mesa farm at Carbondale we found potato roots going less than two

feed in depth, except where alfalfa or sagebrush roots had gone before. These soils are unexcelled for potato growing because, in



Figure 3.—Photomicrograph of a potato seedling at the stage when the root cap commences to lose masses of cells if slightly rubbed.



Figure 4.—The same seedling as Figure 3, more highly magnified.

our judgment, of the slope, which prevents soakage, and of the climate of the region. In a level and warmer country they probably

would not grow potatoes permanently. At Ames, Iowa, in the late summer of 1914, Mr. E. E. Isaac, a graduate student, and the writer dug two large holes in a potato field, which has a good deep loam but which is underlaid by clay and which requires artificial drainage. We found, in gravelly loam, potato roots dead at 4 feet, and standing water at $4\frac{1}{2}$ feet; and in heavy clay loam, roots were dead at $3\frac{1}{2}$ feet with water at $4\frac{1}{2}$ feet. The closer-grained soil drew to a higher level water enough to drown the roots. This condition was found in 1912 at Del Norte, Colorado, where a rise in the Rio Grande River had raised the water level under the potato field.

Laboratory studies of potato roots throw an interesting light upon the field studies. The potato root, in the conditions studied, penetrates raw clay soils not at all. This, doubtless, is not only because in such soils a potato root does not find the amount of air which it needs, but also because its root cap (*C* in Figures 4, 5 and 6) is an inefficient protection to the growing tip of a penetrating root. Doubtless potatoes have grown for so many ages in an open soil that their roots are adapted neither to enter nor to live in very close-grained soils. We find that the root cap loses large masses of cells with the slightest rubbing against soft wet paper. As soon as the seedling develops root hairs, the cap will break up, in this manner and the cap on mature plants is similarly weak.

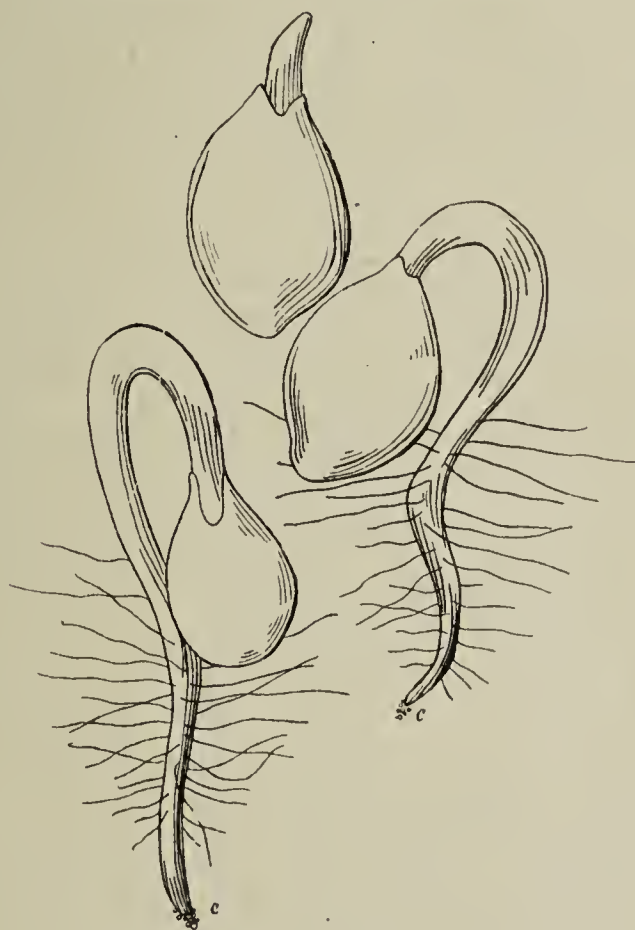


Figure 5.—Germinating potato seedlings, showing loosening of the root caps. These seedlings are from Carbondale Peachblow seeds about 10 years old. Drawing by Ada Hayden.

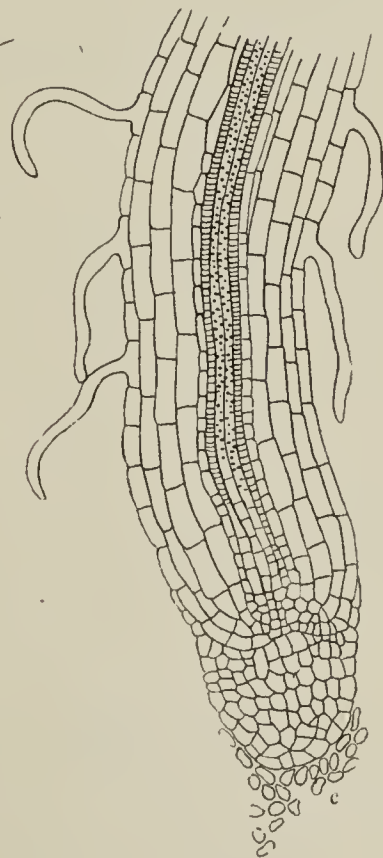


Figure 6.—The root tip of a potato, showing loose cell cap at tip. Drawing by Ada Hayden.

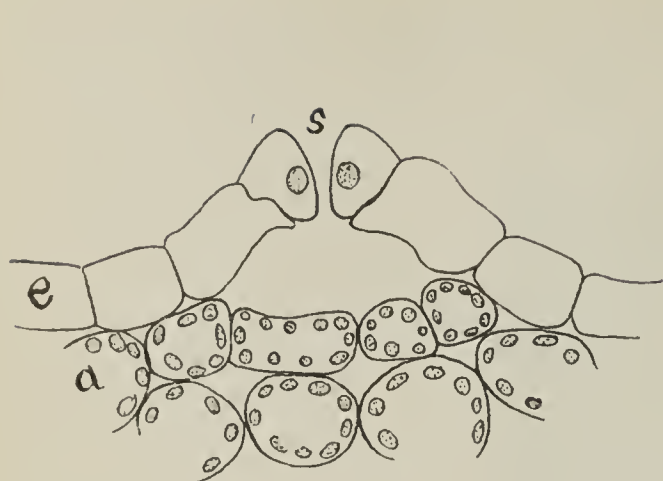


Figure 7.—The stoma or breathing pore of a potato leaf; a structure designed to dissipate rather than conserve moisture. Drawing by Ada Hayden.

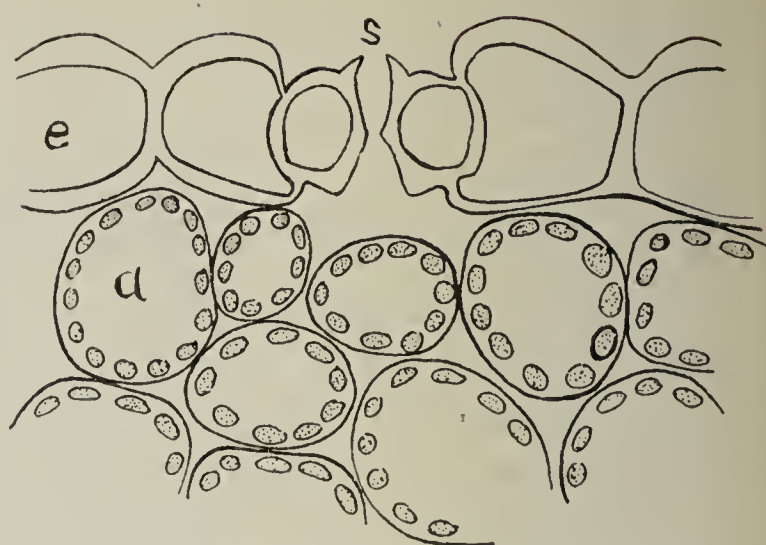


Figure 8.—The stoma or breathing pore of an alfalfa leaf for contrast with that of the potato. A structure designed to conserve moisture. Drawing by Ada Hayden.

Laboratory studies of the potato leaf are of use in studying the needs of the plant. Farmers know that in dark, misty weather potato leaves grow broad and full at the edges and that the crop fairly leaps forward under such conditions. Moisture and temperature conditions in the soil are apt to be right at such times, but the microscope shows that misty weather is particularly good for the leaf itself, and it has been shown, moreover, that starch formation is favored by the less intense light which accompanies such weather. To prove that a damp atmosphere is good for potatoes, we have only to remember the climates of Scotland and of upper Maine.

The stomata, or breathing pores, of the potato leaf (Figure 7) project like little craters and are adapted to the ready escape, on every breeze that passes, of moisture from the scantily protected inner tissues of the leaf. In marked contrast are the stomata of the alfalfa plant (Figure 8) which we know is an age-long native of arid regions. Its leaf openings are protected by being sunken and by having an upper protecting ring about the tiny well. These stomata are adapted to the conservation of moisture.

The evidence of root and leaf seems to prove that the potato plant, if native to mountain regions, must have grown where the soil was deep and open, free from soakage by heavy rains, and where there was much misty weather. That the leaf diseases of the potato—early and late blight—both develop faster in damp weather is evidence of the same sort. The best soil temperatures for potatoes as herein shown have a very narrow range above and below 70 degrees F., and this is very close to the optimum temperature for late blight, which is believed to have lived for ages with

the potato plant. It seems probable that the potato plant was developed by nature on deep, sandy loams in an equable maritime climate. Our mountain potato districts are among the best in the world because of their cool temperature, pure, cool water, abundant slope, and fertile, alfalfa-filled soils. They would be still better for potatoes if their air was damp.

III. GREENHOUSE STUDIES OF SOIL TEMPERATURES AND MOISTURE.

Following the field evidence that soil heat or soakage, or both, had been the occasion of the leaf-roll disease, arrangements were made for the study of these factors under controlled conditions (Figure 2). A preliminary experiment, in which large incubators heated with lamps were used, having proven unsatisfactory because of the impossibility of securing natural conditions of air and light, four cabinets (Figure 2) were made and fitted with racks, for the suspension, in a water bath, of watertight tanks in which potatoes were planted. Each cabinet held 35 tanks, the space which otherwise would have been occupied by the 36th tank being given to the electrical heating and turbine stirring arrangements shown overhead in Figure 2. Six-hundred-watt heating units, such as are used in electric irons, were soldered to lead pipes which protected the connections. The unit was placed in the water directly beneath the turbine wheel, which was set vertically and arranged to draw the water upwards past the heating unit. Power was furnished by a water motor running continuously. One tank in each cabinet was given to the thermostat which operated the magnets, and these, in turn, cut the heating current out and in. In the coldest cabinet, a geared electric switch was used to open and shut a valve in a pipe supplying mountain water at about 33 degrees F. Except for some weakness in construction of the switches, all the mechanical and electrical parts proved to do their work well. The turbine arrangement was particularly satisfactory and maintained the temperatures in the farthest corners of the cabinets just the same as in the center.

The tanks held 25 pounds each of calculated dry earth. Each empty tank was made up to even weight with coarse sand and this sand was used to mulch the earth and prevent puddling while watering. The tanks and calculated dry earth all weighed the same and a lead weight was made to balance this amount. By sacrificing at intervals some six plants and weighing them, we were able to set, on the second beam of our scales, our plant tare and weigh the

water direct, on the other beam, each quarter pound being 1%. These calculations were checked at three intervals against samples of earth taken from the tanks with a butter trier and tested for water by drying in a soil oven.

The soil temperatures used were 50°, 65°, 80°, and 95°. The potatoes planted in earth at 95°, in many cases started to sprout but all were killed before coming to the surface, so that only three cabinets were operated to maturity.

The quantities of moisture used were: 10% for the long row at the left in each cabinet through the entire experiment; 20%

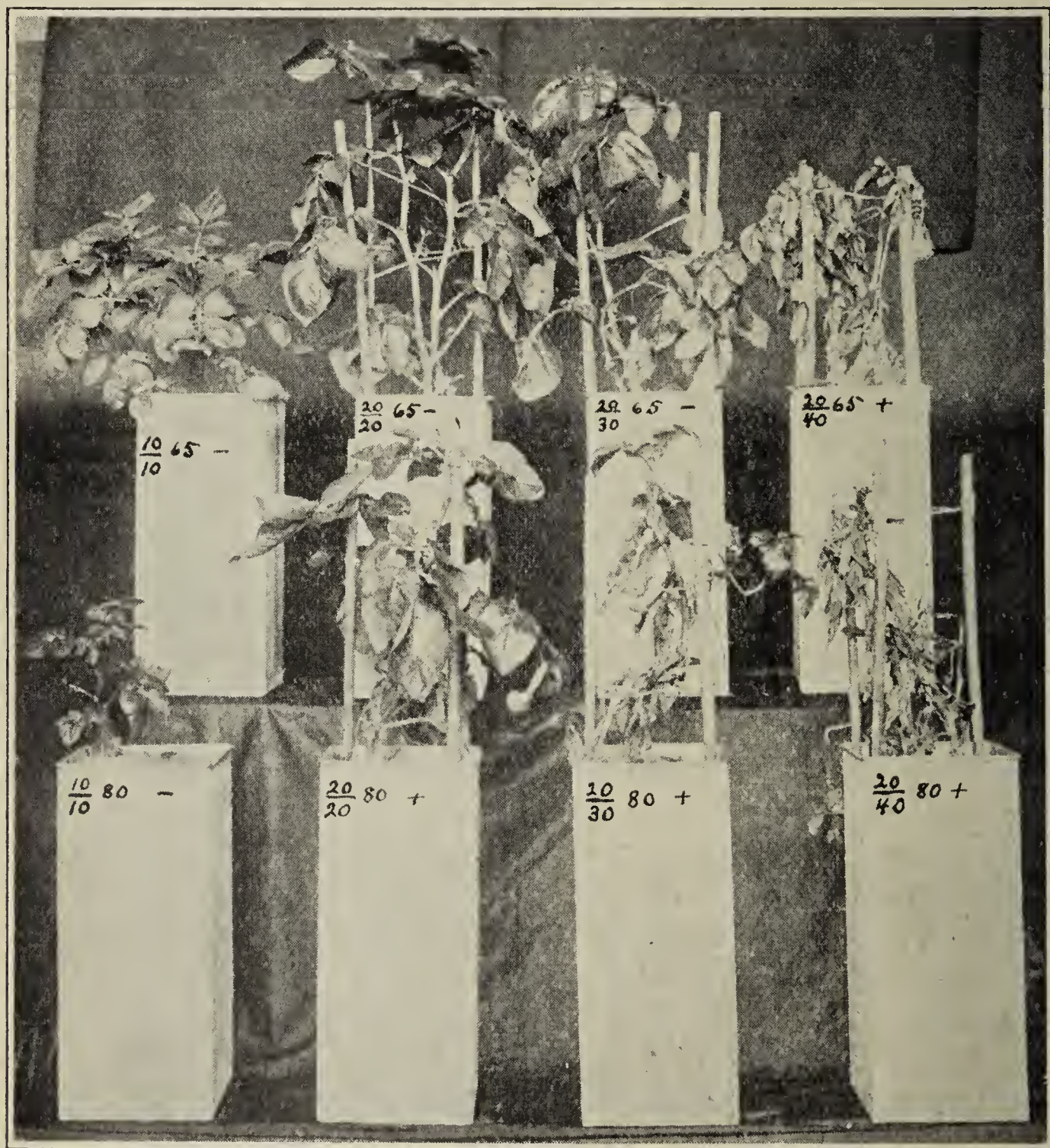


Figure 9.—Plants grown for the whole period respectively at 80 degrees soil temperature (bottom row) and at 65 degrees soil temperature (top row) five days after the right hand plants had been changed from a soil moisture content of 20% to one of 40%, the next plants from 20% to 30%, the left-hand plants remaining at 10% and 20% as from the first. *Fusarium* content negative or positive according to the signs on the tanks.

for all the period in the second row; 20% for 75 days for the third and fourth rows, and then for 5 days 30% for the third row and 40% for the fourth. We did not dare use 30% and 40% during the main growing period because we believed these high percentages of moisture would cripple the plants (see Figures 9, 10 and 11).

We found that when the moisture in the 10% row fell to 7%, the plants wilted, and that they recovered all right and quickly when watered again. In practice, we ran the water from 2 or 3% above to 2 or 3% below the standard.

The soil used was a mixture, about half and half, of a light, sandy loam from Farmers' Spur near Greeley and clay loam from an alfalfa field on the college farm at Fort Collins. The sandy loam was from a field where leaf-roll had been serious during 1911, and the seed potatoes were Pearls from the same field. The study was made to determine what conditions would bring health and what conditions disease. The potatoes were planted on February 5, 1912, and the temperatures and percentages of moisture were maintained from that date.

The health of the 10% lots, whether in cold, medium or constantly warm soil, was in entire accord with the experience of practical potato growers under irrigation. They find that almost no harm comes in early summer to dry plants, even though the sun be steadily hot and the soil hot. If obliged to irrigate at such times, they do it at night, but the wisest of them often let potatoes get very dark and the leaves droop, hoping for cool weather and showers to put the plants along to where they will shade the ground before irrigating. Then they uniformly practice, on the more level fields, irrigating every other row only, until the vines have reached good size. Some irrigate alternate rows at the second watering and others irrigate the same alternate rows each time until cool weather or self-shade, or both, are at hand. We favor the latter method, because it leaves half of the surface mulched and half of the roots free from soakage while warm.

In times of great scarcity of water less has been used and good crops have been made by irrigating the same alternate rows throughout the season. Dry times are hot times and reservoir water used then is both warm and extremely alkaline. By a principle well known to botanists strong alkalinity makes it somewhat more difficult for the plants to secure water enough for their needs. Conservative irrigation to avoid root injury at such times is imperative for health and a good crop. It is equally reckless in cost

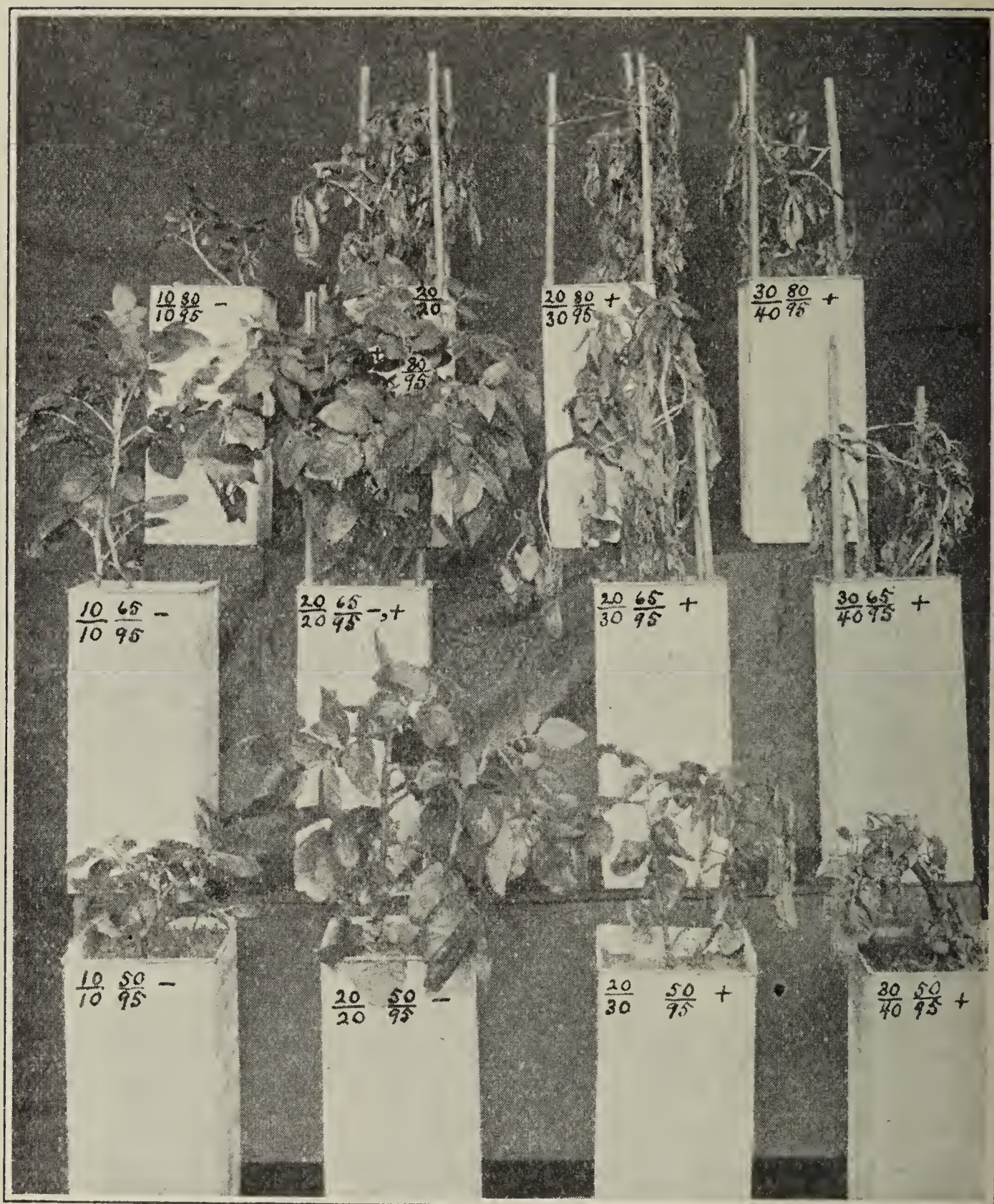


Figure 10.—Plants grown at 80° (top row), 65° (middle row) and 50° (bottom row) for two months and then transferred for five days to a soil temperature of 95°. The right-hand plants were raised from a moisture content of 30% to one of 40%, the next from 20% to 30%, the left-hand ones remaining at 10% and 20% respectively. The *Fusarium* content is marked on the tanks as follows: *Fusarium* found, +; *Fusarium* not found, —.

of water and risk of crop to be prodigal with water on lands with little slope in hot weather.

Observations stated, and to be stated herein, are the basis of the following principle which should govern irrigators of potatoes:

Heat, soakage, infection, continuous cropping with potatoes, alkali water, poor seed, poor fertility are all against potato health.

The more we have of one condition, the less we can have of the others if we are to make a good crop.

When the higher percentages of moisture were used, the leaves and stems collapsed very quickly, within less than a day, in the 80° cabinet, somewhat less quickly in the 65° cabinet, and not at all in the 50° cabinet. It is to be supposed that the roots were in better condition in the cooler cabinets and were less easily drowned. The effect of the high temperature and soakage was, evidently, the crippling of roots by heat and the exclusion of air, so that the roots could not supply the tops, which then wilted for lack of water.

After 90 days the stems were cut just beneath the soil and were submitted for examination to Professor Walter G. Sackett, of the Colorado Experiment Station. He found a species of *Fusarium* present in some of the stems and absent in others, according to a very definite rule. As the examinations were being made we were able to foretell in advance whether or not the *Fusarium* would be found. The results were absolutely uniform. There were no exceptions.

We regard the presence or absence of the fungus in these experiments as a secondary matter; as an index of the health, or lack of health, of the plants under the conditions to which they

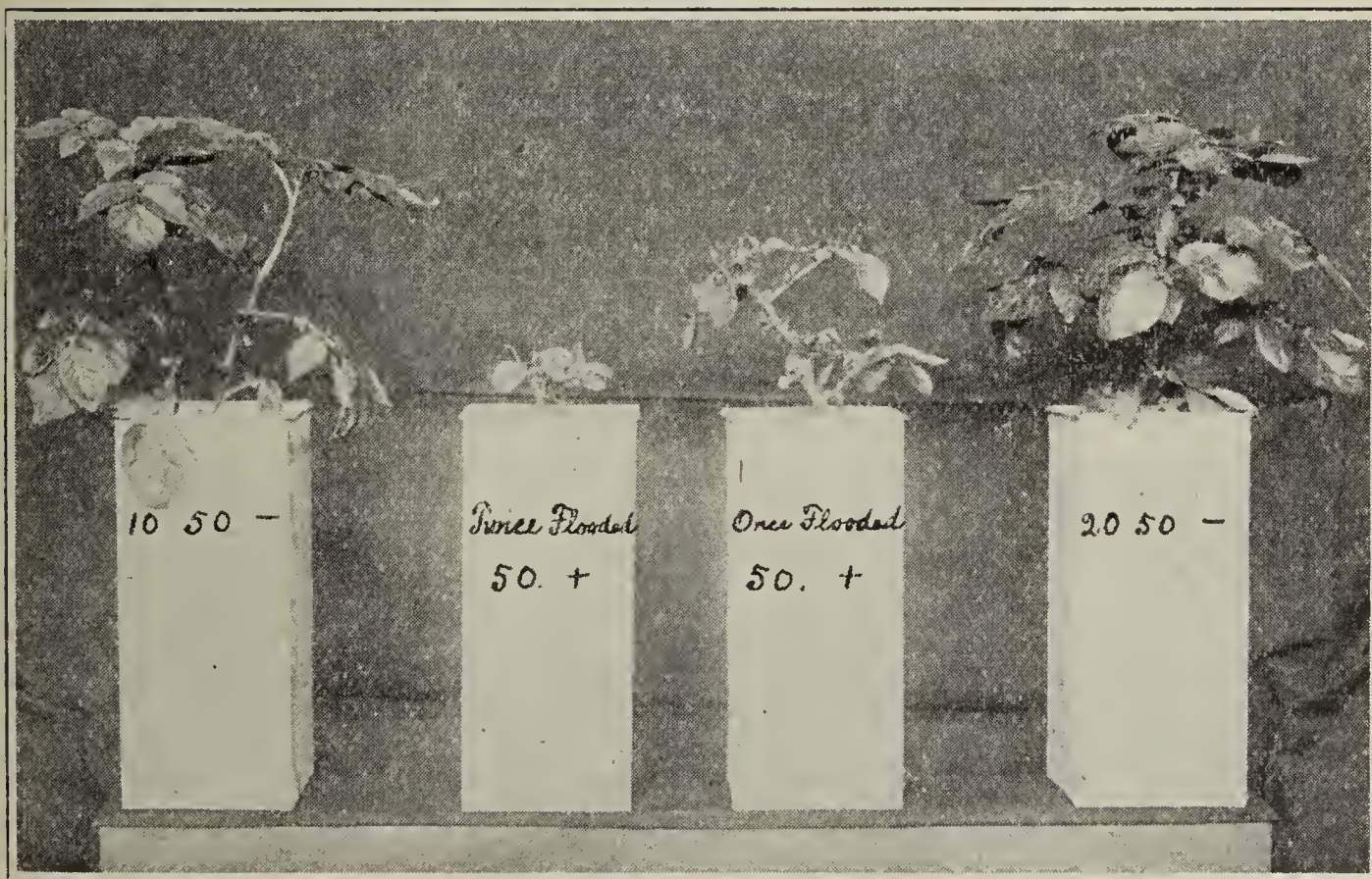


Figure 11.—From left to right: 1. Moisture at 10 per cent (8-12) negative. 2. Twice flooded. “*Rizoc*” and *Fusarium*. 3. Started at 10, once flooded by accident. “*Rizoc*” and *Fusarium*. 4. Moisture at 20 per cent. Check, the same. Both negative. Note the abundant health of the plant on the right, though grown from leaf-roll seed in leaf-roll soil.

had been subjected. Later herein we shall give the field evidence that there was in Colorado a fungus or infection factor in the leaf-roll disease.

Figures 9, 10 and 11 show the condition of the plants after 80 days of growth. The sign (—) means that *Fusarium* was absent and the sign (+) means that *Fusarium* was found. The first figures are the percentages of moisture used, the second the temperatures. Where another number is used below a line it represents the condition as changed for the last five days.

The following table, Figure 12, shows dividing lines between plants injured and not injured by *Fusarium* because of heat and soakage.

$\frac{10\%}{10\%} \frac{65^\circ}{65^\circ} -$	$\frac{20\%}{20\%} \frac{65^\circ}{65^\circ} -$	$\frac{20\%}{30\%} \frac{65^\circ}{65^\circ} -$	$\frac{20\%}{40\%} \frac{65^\circ}{65^\circ} +$
$\frac{10\%}{10\%} \frac{80^\circ}{80^\circ} -$	$\frac{20\%}{20\%} \frac{80^\circ}{80^\circ} +$	$\frac{20\%}{30\%} \frac{80^\circ}{80^\circ} +$	$\frac{20\%}{40\%} \frac{80^\circ}{80^\circ} +$
$\frac{10\%}{10\%} \frac{50^\circ}{95^\circ} -$	$\frac{20\%}{20\%} \frac{50^\circ}{95^\circ} -$	$\frac{20\%}{30\%} \frac{50^\circ}{95^\circ} +$	$\frac{30\%}{40\%} \frac{50^\circ}{95^\circ} +$
$\frac{10\%}{10\%} \frac{65^\circ}{95^\circ} -$	$\frac{20\%}{20\%} \frac{65^\circ}{95^\circ} +$	$\frac{20\%}{30\%} \frac{65^\circ}{95^\circ} +$	$\frac{30\%}{40\%} \frac{65^\circ}{95^\circ} +$
$\frac{10\%}{10\%} \frac{80^\circ}{95^\circ} -$	$\frac{20\%}{20\%} \frac{80^\circ}{95^\circ} +$	$\frac{20\%}{30\%} \frac{80^\circ}{95^\circ} +$	$\frac{30\%}{40\%} \frac{80^\circ}{95^\circ} +$
$\frac{10\%}{10\%} \frac{50^\circ}{50^\circ} -$	Flooded Twice 50° +	Flooded Once 50° +	$\frac{20\%}{20\%} \frac{50^\circ}{50^\circ} -$

Figure 12.—Giving summary of greenhouse studies of potato health. Percentages of water in soil and temperatures of soil for first seventy-five days shown above the line, and for the next five days shown below the line in the form of a fraction in each case. Presence of disease is shown by a plus (+) sign. Absence of disease is shown by a minus (—) sign. Note that the combination of adverse factors governing the appearance of *Fusarium* in the ducts is limited by the solid lines drawn through the table. As the water was applied to the surface, the distribution of the water was not quite uniform throughout the soil, and it is therefore believed that a line somewhere near the position of the dotted line would more accurately represent the boundary.

It would be desirable to repeat this experiment in summer, in dry air and sunshine, out of doors. There would be likelihood of producing the leaf-roll disease in typical form in some of the conditions and entirely healthy plants in others.

Every warm summer, in the corn belt, potato leaves roll as they did in the epidemic of leaf-roll in Colorado, but they usually recover to a large extent, with good fall weather. For many years, in the Greeley district, if leaves were once rolled by long continued heat and heavy soil and heat, or watering in hot weather, all chances for a real good crop were considered to be past. There is a strong probability that it is the fungus factor that makes the leaf-roll condition permanent. It seems to be the sum of poor nutrition, a starvation matter, due to root injury.

THE INFLUENCE OF SOIL, HEAT AND WARM AIR.

On April 8th, the plants in one cross row were transferred from each of the other cabinets to the 95° cabinet, and part of them were covered with a glass case, heated by two 32 c. p. carbon lamps to

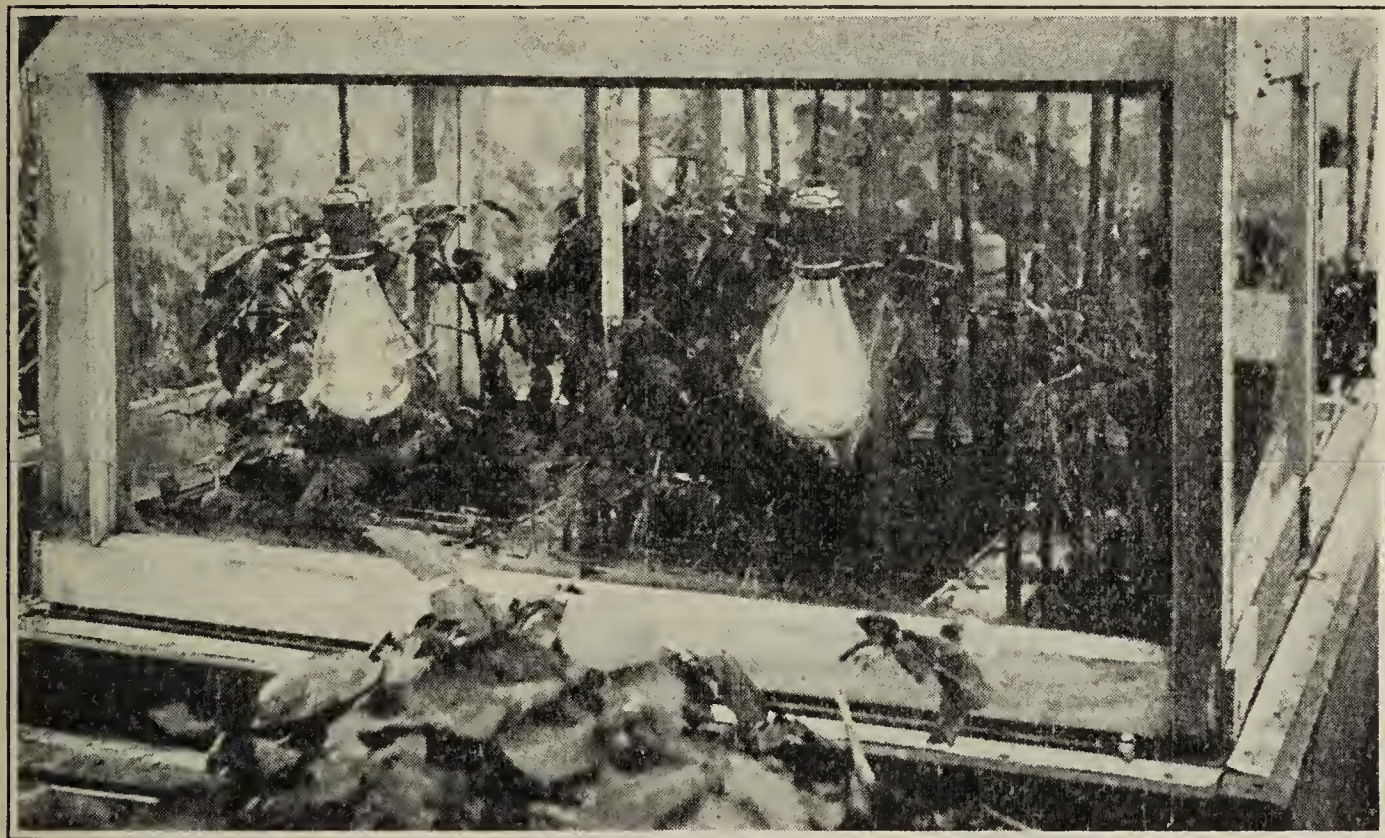


Figure 13.—A case in which summer air temperatures were produced by heating with large electric globes. The temperature of the air proved to be a comparatively unimportant factor of potato health.

an average temperature of 90° (ranging from 75° at night to 110° in the sun) and well ventilated, to simulate summer heated air. We give the detailed records with the cuts and in the table. (See Figure 13.)

Those plants which had been wet and warm were almost instantly wilted by transference to the 95° cabinet. Those that had been dry or cool stood up much longer. The addition of heated air in the glass case made very little difference to the plant troubles or in the time of going down from the soil heat.

IV. FIELD STUDIES OF HEAT AND SOAKAGE AND OTHER FIELD OBSERVATIONS.

Through the co-operation of the Board of Commissioners of Rio Grande county, who furnished the equipment, and of Mr. R. A. Chisholm, who cared for the work and took the yields, a field experiment to determine the best level of water for the sub-irrigation of potatoes was performed during the season of 1912 at Del Norte in a mellow, sandy loam soil.

Four watertight galvanized iron tanks, four feet long, four feet deep and two feet wide (Figure 14) were set in the ground flush with the surface. In a corner of each a five-foot piece of corrugated galvanized iron eavestrough piping was placed upright, the lower end being notched and placed on the bottom of the tank. To



Figure 14.—Setting tanks for the study of the best water level for the sub-irrigation of potatoes.

prevent clogging, the bottoms of the pipes were surrounded with a little pile of good-sized pebbles. Then the tanks were filled with earth, and Pearls were planted in each.

A record of rainfall was kept, and deficiencies from an average rainfall were made up by sprinkling a calculated amount of water upon the top of each tank. Additional water was run down the pipes, through which, also, the water levels were measured so

that the ground water level was kept at one foot from the surface of the soil in one tank and at two feet, three feet and four feet for others. Numbering the tanks according to the distance to water, the results were as follows:

YIELDS FROM SUB-IRRIGATION TANKS.

Tanks	Nos.	Total Weights of Tubers	No. of Large Tubers	No. of Culls	Quality
1	4	3.5 lbs.	13	23	Very poor
2	3	6.0 lbs.	12	8	Poor
3	3	9.0 lbs.	17	8	Fine
4	2	6.5 lbs.	12	18	Good

It was regrettable that an even number of hills were not secured for comparison, but it was very evident to the observer that, for the fine, mellow garden loam used, three feet deep is the proper level for the irrigation water where subbing is practiced. The leaves of the plants in No. 1 and No. 2 were badly rolled, and the potatoes inferior. In No. 3 the tubers were larger, few were small and the total weight of tubers fit for table use was most in the aggregate and per hill. No. 4 showed signs of drouth and did not make as many of its tubers of desirable size as an average plant should produce.

It is the keen desire of many thoughtful men that eventually the sub-irrigation system may be eliminated. It is calculated that row irrigation will take less water per acre and that the drainage system that should be installed with a new system of irrigation will make it possible to use the water several times, and largely increase the acreage that can be planted, and the prosperity and future security of the agriculture empire, which lies west of the magnificent Sangre de Christo range.

At Greeley, in 1912, in co-operation with Mr. E. R. Bliss, two experiments were performed in studying the conditions necessary for potato health. One small patch of ground was shaded by a

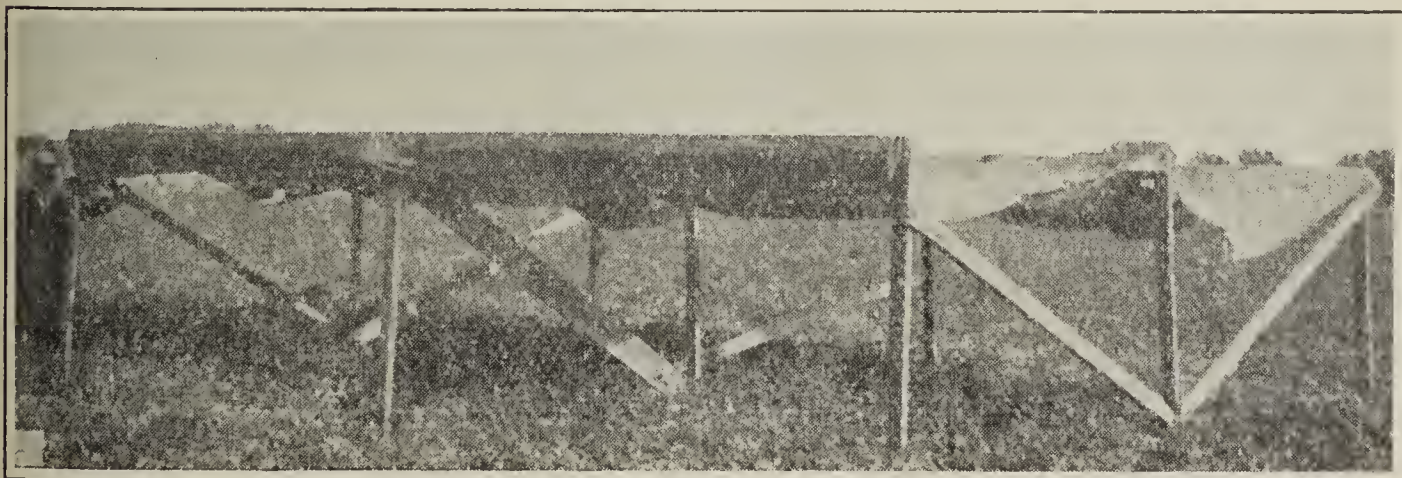


Figure 15.—Shading the ground did not do much good in 1912.

canopy (Figure 15) and soil temperature records kept, but it was found that the shaded plants were but little, if any, better than the average. It was true of 1912 in general that conditions of temperature were good, but that the crop was almost as badly affected by leaf-roll as in 1911.

A large cold frame (Figure 16) was placed over another small patch of hills with the idea that the additional heat might make the disease worse. Soil and air temperatures were higher but the light

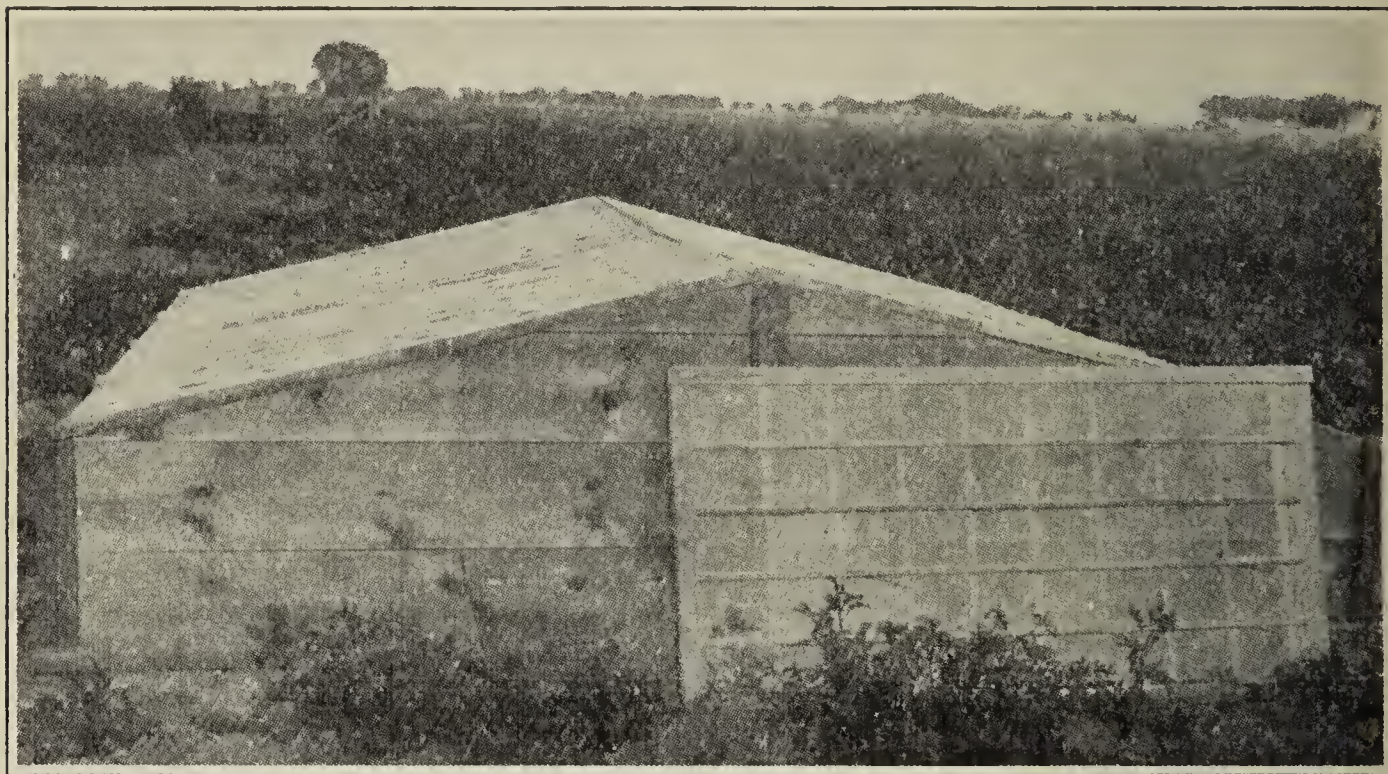


Figure 16.—Trying to hold some field plants still warmer by covering them with a large cold frame. The results were not what was expected.

was more subdued and evaporation, and undoubtedly transpiration, were less. The plants, much to our surprise, were rather better than elsewhere in the field, and did quite a little growing late in the season, after other plants were done.

The effect of cultivation upon soil temperature is not to be overlooked. The heat rays pass through the air and warm it hardly at all. The air is heated, by radiation, from the surface of the earth, which absorbs the sun's rays. If the surface of a potato field is loose and dry it may be very hot, but comparatively little heat goes deep into the earth, and when the sun has set, the earth and air above cool quickly. This is the condition in a desert, where the surface is loose sand, and this should be the condition in a potato field in a region of intense sunshine. Every barefoot boy knows how much hotter road dust is than solid earth. The road dust is letting less heat down into the soil, is hotter itself, and for the time being is giving off more heat by radiation.

For three years we carried a pocket thermometer for the observation of the temperature of soil and water. Under a bright sun,

very high surface temperatures have been observed. At Briggsdale, on July 16, 1912, in a patch of potatoes in a garden we found a surface temperature of 133° (It has reached 142° in the writer's garden at Ames, Iowa), while at four inches the temperature was 81° . The surface temperature in the shade of a potato plant was 93° , on the center of a hill 80° , and four inches deep, 74° . Sandy road dust was 130° , and the side of an ant hill was 135° , and level coal dust was 134° .

Because the Greeley district slopes to the sun, slightly more heat per square foot is absorbed than would otherwise be the case. At Ault, on July 13, 1912, at noon, road dust piled on a newspaper in the full sun was 130° on the side facing the sun and 123° on the side sloping away from the sun. That afternoon at 1:30 in a crusted potato field near the pea huller, the temperature was 110° , at three-fourths of an inch below the surface, and at five inches, 84° , which are dangerous temperatures for potatoes. At the same time, in a well cultivated beet field, the top soil was 115° and at five inches the instrument read 78° .

At 3 p. m. on June 22, 1912, on the Rasmussen Brothers' farm five miles east of Greeley, in a crusted potato field, the temperature at the seed pieces was 89° . In a portion of the field cultivated the night before the temperature at the seed pieces was 75° and in rows cultivated that morning, 72° . Driving out the next morning to the same place at sunrise, the temperatures at seed pieces were found to run about 67° , at eight inches deep 70° ; and at fifteen inches 70° . The air at 5 o'clock, five feet from the ground, registered 54° . As the sun came up, shallow temperature changed almost instantly. In the sun at 5:30 surface soil temperatures were 70° , in the shade of a row 62° , in a horse track 57° . Mr. Charles Rasmussen suggested the use of a beet cultivator to break the crust without destroying the planter ridge.

The above temperatures are typical of hundreds taken. The eight to ten inch cultivation, which is the universal practice of potato growers in the Greeley district, is needed to hold the soil open for protection against the effect of heavy rains, and to make a good ditch possible. but we are fully persuaded that it is necessary, also, to influence deeper rooting early in the season and to provide a very deep, porous blanket against the entrance of heat.

In 1914, Mr. E. E. Isaac, a graduate student, working under the author's advice, found that at Ames, Iowa, in less intense sunshine and with less thorough cultivation than is practiced at Greeley, deep cultivation (6 to 7 inches) as compared to shallow cultivation (3 inches) made the soil at a depth of the seed piece, on the average,

between two and three degrees cooler in the warmest part of the day. On extremely hot days the saving at the high point was sometimes as much as 7° . The deeper rooting would be a factor also in favor of deep cultivation, as the deeper the roots the less their temperature at the top heat of the day. With heavy soils, the poorer aeration of the roots at several inches below the surface would be an adverse factor, but potatoes should not be planted on such soils in regions of high soil temperatures.

The temperature of irrigation water is an important factor, also, because water holds from seven to eight times as much heat as good potato soils, so that the temperature of such a soil is profoundly influenced by the temperature of the irrigation water. Water coming a long way in small ditches is considerably warmed. A return to the planting of trees on ditch banks would have some excellent results. To mention an extreme case of warm irrigation water, we found near the lower end of one of the ditches out of the Poudre, one afternoon in July, 1912, a potato field being irrigated with water which was reaching the lower end of the field at 108° . At Glenwood Springs, in the same month, we found the Grand river at about 52° , and the Roaring Fork water going into the potato rows from the snows of Mount Sopris at 54° .

V. HISTORY OF POTATO-GROWING DISTRICTS.

As our fathers have cleared new forests, moved west to new prairie lands, or brought into cultivation by their labor and engineering skill the new and wonderfully fertile irrigated districts of the West, they and we have had for almost three hundred years new lands on which to grow potatoes. Virgin soils produce well nourished, well rounded tubers from healthy plants. As virgin soils are no longer available, we shall be obliged to consider with care the soil requirements for the health of potatoes. As time goes on, our loose, sandy soils, sometimes held in little respect, will be better fertilized and more appreciated because of their healthfulness for potatoes.

At the Colorado station, no question came more often to the potato specialist than: "Why cannot we grow potatoes? We did here in the early days, but we cannot now." Only recently an Iowa man who had bought land near Denver sent the same question to Iowa State College. This question came very often from the vicinity of Rocky Ford, from Canon City, from Pueblo, from Rye. from the Fountain Valley below Colorado Springs, from Golden and Denver, Longmont, Stove Prairie and Virginia Dale. The

Arkansas divide once shipped potatoes by the trainload. The crop failed, as did likewise an attempt by the Colorado station to grow potatoes at Elizabeth, under improved methods, in 1909. This crop was harvested by the writer.

On Clear Creek and Bear Creek near Denver, in 1863 or 1864, according to Mr. Asa Sterling, of Greeley, one crop of potatoes, of excellent quality, was raised but none have been raised since.

On the present site of Denver, in the suburban region west of Denver University, potatoes were raised in the early days and of good quality. On August 19, 1912, we visited the locality, talked with gardeners and small farmers and saw the brick residence, spacious for its time, of the man who was known as "Potato Clark," because of his great success at that place with potatoes grown for Denver and the mining camps, in the early days. We later had a gracious letter from his widow, an elderly lady in the East. All were agreed that potatoes had failed about 1876 and, though often tried, they have not been grown thereabouts with any success whatever for forty years.

The same was true later, but in less degree, of the farms about Longmont, Johnstown and Fort Collins, on soils so rich that they grow the largest yields of sugar beets and grain produced anywhere.

The plants, in such of these cases as have been observed, appeared to have the leaf-roll disease. On the station plots at Fort Collins Professor E. R. Bennett, in the years 1907 to 1912, secured about one fairly healthy crop in the six.

Down the Platte river, at Brush, and at Julesburg, where the yields were formerly very large, failures came sooner than on less rich soils. In 1915 crops of potatoes have been good again, the Greeley district having one of the best crops it ever raised. The worst crop was in 1911, but the crops of 1912, 1913, and 1914 were far below the average.

On the West Slope there are heavy lands which have gone out of potato production—mostly bottom lands that have had the leaf-roll. Other bottom lands and damp spots at the breaks between benches, will have trouble, but the high sloping mesas, with their pure, cold water, have fine conditions for permanent potato production.

THE EVIDENCE OF A FUNGUS OR INFECTION FACTOR IN LEAF-ROLL
DISEASE IN COLORADO.

First.—The two regions which had the disease the most severely are tied together by one of them securing the major portion of its seed from the other.

Second.—In the Greeley district, in 1911, the soil heat would lead us to expect trouble, but the weather conditions in 1912 were ideal. In that year the United States grew the largest crop of potatoes that it ever grew and had the largest yield per acre since the Government has made estimates of yields. Nevertheless, the crop in the Greeley district was very little better than in 1911, in spite of new seed, and much change in crop rotation. Some active factor of infection must have been carried over in the soil, and must have been distributed universally over the district by wind, water, tools and potato storage.

Third.—With decreased acreage of potatoes for 1912, 1913 and 1914, and a season in 1915 showing a large deficiency in temperature (according to the September report of the Denver branch of the Weather Bureau) for May, June, July and August, and some deficiency for September, but no better a season than 1912 and with change of soil and seed as in 1912, the Greeley district has a record crop on a small acreage. Some hidden injurious factor has been lessened.

Irrigation water affords a ready means for the distribution of any microscopic life, and I am indebted to Dr. L. R. Jones, of the University of Wisconsin, for his opinion that *Fusarium* might be distributed by the wind.

In Iowa, conditions which potatoes have to meet are much the same as in the Greeley district. We have less soakage, but we have large areas requiring artificial drainage and much soil which is heavier than that at Greeley. We have more heat. We have no district that has for a long time specialized, with success, in potatoes. No less than five districts that once grew many potatoes are producing less, and some none, for shipment, and in all such districts poorer shape and yields have been reasons for reduction of acreage. We have one area of deep, sandy loam, naturally drained, that promises to produce many potatoes permanently. We have another very large area of deep, loess soil, naturally drained, where potatoes do well. We have no large area on tile-drained soil where potatoes are a reliable crop.

We may regard it as an axiom that where seed potatoes cannot be maintained for some years conditions for potato health are not the

best, and that where seed potatoes can be maintained for years, conditions are good. The author has found the following instances of permanency and health in a State most of whose area finds it desirable to send away for seed:

Mr. W. C. Boyce, Winterset, Iowa, has maintained Bonanza potatoes on the same farm for 29 years. His farm is very large. He raised but five to ten acres of potatoes on portions of the farm that are extra well drained.

At West, Iowa, Anton Neuman, potato man for one village of the Amana colony, has maintained Snowflakes for 37 years. He has deep, mellow, sandy loam. There are no other potatoes than his raised or used for a distance about the village.

At Tabor, close to the Missouri line, Mr. Ed. L. Gladwin has maintained the same stock of Vick's Champion potatoes for 27 years. His soil is deep, self-draining loess and he raises but one or two acres on a considerable farm.

At Auxvasse, in central Missouri, Mr. I. J. Attemron maintained Early Rose for 31 years and then lost seed accidentally.

The soil and climatic conditions for health of cabbage are very much the same as for potatoes. The Amana society has grown cabbage as one among a full line of vegetables, on sandy loam in Iowa county for 60 years without serious disease. In the second county east, in a specialized cabbage district, cabbages cannot be grown safely more than one year on the same ground. Often



Figure 17.—The health needs of cabbage are much like those of potatoes. Among cabbages are found plants which do not have the yellows or *Fusarium* disease. Their progeny is for the most part resistant also. In the center is shown on sick ground healthy cabbages which produced 20 tons per acre, where plants from other seed, on right, were all sick.

whole crops are destroyed by the yellows, a *Fusarium* disease, and the lands stay sick to cabbage for an unknown number of years.

VI. THE HOPE OF DISEASE-RESISTANT POTATOES.

Among cabbages there are found a few that do not have the disease and their seed produces plants most of which do not have the disease, as the author has shown in Muscatine county, following the work of Dr. L. R. Jones, in the Racine district of Wisconsin. To have an equal chance of finding such plants among potatoes, a vast number of seedlings would have to be produced, and in the Greeley district practically no seed is borne except by the Pearl bastard. If, among many hundreds of thousands of its seedlings, a goodly number of resistant plants were found, it might be possible to find one worthy to use as the commercial variety of the district, but all these seedlings and all the seed stock of any worthy variety would have to be produced elsewhere under better conditions for health and then be brought to the regions of greater strain upon health in potatoes. The price of a small battleship would be required to carry on breeding work on a scale vast enough to promise success under such difficulties.

VII. SUMMARY.

Leaf-roll, regarded as the sum of ill health for potatoes in Colorado, appeared widely and suddenly in 1911, continued in 1912, 1913 and 1914, and disappeared in 1915.

Soils in the Great Plains region may reach dangerous temperatures in years of more than average sunshine. Potatoes were found badly injured in good, but overheated, potato soils, but heated air, constantly changed, seemed to add very little to the ill health of the plants.

In 1911, temperatures for the critical month of June, for the whole upper foot of soil, averaged, in the locality most affected, 10° more than in June, 1910. In other regions there was much injury from over soakage of potato lands.

Potato roots use as much as four feet of suitable soil, but do not enter very close-grained soils, and die in wet soils. The potato root cap offers additional evidence that potato roots have the power neither to enter nor to live in close-grained, easily wet, and poorly aerated soils. The structure of the potato leaf and practical observations indicate that a damp atmosphere is best for potatoes.

Potato plants grown under controlled soil temperatures and percentages of moisture gave evidence that soil heat and soakage

(causing lack of aeration) are joint factors adverse to health of potato roots and plants. These factors were in direct relation to the presence or absence of *Fusarium* hyphae in the water tubes. Irrigation practice and experience also prove that heat and soakage are adverse factors that should not be combined.

Field studies of sub-irrigation indicated, in a certain sandy loam, that three feet was the best depth to water, and that a higher water level was injurious and a lower level insufficient.

Indifferent results were secured by shading and by covering plots of potatoes with glass.

Deep cultivation is approved by practice, by field observations and by experiment as a means of protecting potato roots from extreme temperatures.

The temperature of irrigation water varies widely, and is an important factor because of its high specific heat as compared to that of potato soils. Cold, pure water is best for potatoes.

We have had new ground for potatoes in settling up a new country and a new State. Many districts have become quickly unable to grow potatoes at all, the heavier soils in warmer regions going out first.

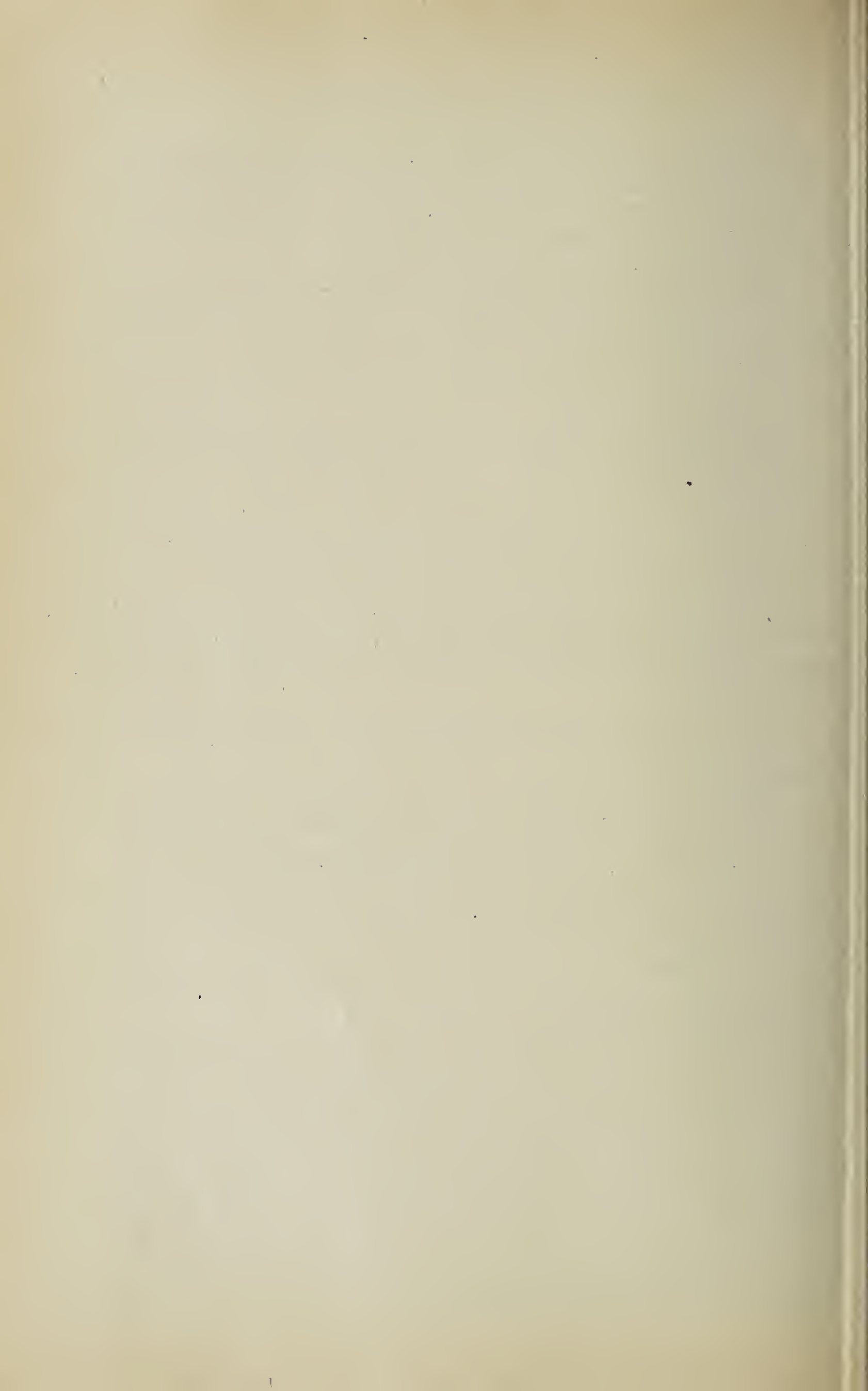
There has been conclusive evidence, in-the-large, that the leaf-roll in Colorado, in addition to heat and soakage, had an infectious or fungous factor.

Cabbage plants, resistant to similar conditions, are readily secured thru selection and their culture is successful in a commercial way on "sick" land. No resistant plants among potatoes were seen. Only a few sorts of potatoes are grown, and hundreds of thousands of seedlings would be necessary for the selection of resistant plants. Almost no pollen was found except on the Pearl bastard, under leaf-roll conditions.

Seedlings, when secured, could not be developed successfully under leaf-roll conditions.

General Summary.—In potato health, soakage, close-grained soils and poor aeration of soils give the same results. *Soil heat, poor aeration, and infection* are the three factors adverse to health in potatoes. The less a district has of one adverse factor, the more it can stand the other two. The more open and cool a soil, the better it is adapted to potatoes; the heavier, damper and warmer a soil is, the poorer is it adapted to potatoes and the quicker will the crop fail.

Regions having fair conditions for health of potatoes can only hope to grow their crop permanently by planting a very small proportion of the area in this crop each year.



Bulletin 217

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A STUDY OF COLORADO WHEAT

BY W. P. HEADDEN

Part II

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A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART II

In Part I of this study (Bulletin 208) we gave the results obtained during the season of 1913 in a study to determine the moisture in the soil, the variations of the nitric nitrogen in the soil, the various nitrogen compounds in the plants from the time of bloom till the wheat was ripe, and also the ash constituents of the plants.

The nitric nitrogen in the plants was not given because we wished to repeat our work on this subject. Our results were not concordant, neither did they agree with such data on the subject as I was able to find. Jost, in his Lectures on Plant Physiology, makes the statement that the air-dried plant may contain from 1.8 to upwards of 2.0 percent of nitric nitrogen, but says nothing about its occurrence in the green plant. He does not say whether it always occurs or not; the impression made by his language is that it may or may not be present. The quantities given are so far in excess of anything that we found, that we deferred any consideration of the subject at that time.

The ash constituents of the plants were given for some samples taken in 1913 and of one series taken in 1914. This last series was taken when the plants were entirely ripe and were really straw; the other samples were much less mature. This difference in the development of the plants at the time that they were cut lessens, in some degree, the value of the results for the purposes of comparison, but does not detract from their value in showing the effects of the fertilizers applied to the different plots upon the mineral constituents of the ash.

The purpose of this preliminary work has been stated to be the finding out of the distinguishing character of Colorado wheat, if it has any, and to ascertain if possible those factors in our conditions which determine this character.

With this purpose in view, and to establish what the effects of

the individual fertilizers are, we studied the composition of the plants from the time of blooming till they were mature. This was done to enable us to draw some inferences, at least, in regard to the part played by the soil constituents as distinguished from the climatic conditions. We hoped by applying nitrogen, phosphorus and potassium separately and each in varied quantities, to so increase the characteristic effects of each, that it would enable us to recognize their specific effects, not merely upon the composition of the plant, but also upon the characteristics of the grain. This procedure was based upon the assumption that the land used in our experiments already contained these elements in sufficient amounts, and in such relative quantities, that it would produce wheat which would be entirely normal for our locality, and that by adding sufficiently large quantities of these individual substances in proper form, we would be enabled to recognize their respective influences upon the grain, and particularly upon the bread-making qualities of the flour. While the composition of the flour, especially in respect to what we may designate its minor details, may have less effect upon the quality of the flour than we think, it is certainly wise in this case to be as thorough as possible, even if our effort produces but few usable results. I have in mind that it is customary to consider the amount of nitrogen in a wheat as indicative of its merit for making flour, assuming at the same time that all other constituents are either present in sufficient quantities, or are of so much less importance that mention of them is not called for. It is not intended to state that the importance of phosphorus or other ash constituents are never considered, for this is not true, but that the importance attached to the amount of nitrogen contained in the wheat overshadows that of the other constituents. Our general judgment is that the higher the nitrogen, the better the flour that it will yield, that is, the greater will be the amount of gluten contained. In this general view, only the total amount of nitrogenous substances is considered; neither the quality of these substances, gluten, nor the presence of other substances which, in the end, may have a deciding influence upon the quality of the flour, is given any weight. There is a large mass of literature upon this subject, but there are not any fixed criteria which may be used in judging the value of flour, nor is there any agreement as to the causes of the differences found in flours or wheats grown in the same, or in different places.

The portion of this work already published (Bulletin 208) shows that the nitrogen supply in the form of nitrates in the soil affects the amount of the total and also that of the proteid nitrogen in the plant throughout the period between blossoming and maturity.

The ammoniac and amid nitrogen found in the plants probably

represent nitrogenous compounds in a transition stage, at least to a large extent; still it is true that we find these more abundant in plants grown with the application of nitrates than in others. We further found that the effect of phosphorus, and also that of potassium, upon the total nitrogen in the stems, leaves, and heads was very small, until the period of ripening approached, when these elements seemed to effect an increase of the total nitrogen in the heads, but the proteid nitrogen in the heads of wheat plants dressed with phosphates or potassium salts was not greater than in those of plants that had received no fertilizer.

The mineral constituents of the plant were also affected by the application of the nitrate, but not in a uniform manner, some constituents increased while others were depressed. Calcium, magnesium and potassium (sodium is included) were increased, silicon was decidedly depressed, but the phosphorus in the plant did not seem to be affected. This statement pertains only to the plant and is not to be applied to the grain, which will be discussed later.

The effect of the application of water at different times was not studied, except by the results obtained on one plot which received a total application of two feet of water, one applied 12 June and the other 12 July, 1913. Four plots were irrigated on these dates, but plants from only one of these were analyzed. The effect of this increased water supply upon the amount of total and proteid nitrogen in the stems, leaves and heads of the plants was not marked enough to justify, in any measure at all, a statement that any results had been produced. The same statement applies to the yield of both total dry-matter and of grain, for in none of the four experiments was there an increase in either respect. The application of one acre-foot of water on 12 June, when the wheat was in boot, was sufficient for the production of a maximum crop.

The soil moisture for the season of 1913 is given in detail in Part I (Bulletin 208 of this Station).

It will be recalled that in the plan of these experiments every fourth plot was a check. The above statements are all based upon a comparison of results obtained with plants from these check plots with those obtained with plants from the plots to which we applied fertilizers.

It was impossible for us, during the season of 1914, to carry out the plan pursued in 1913, so we were not able to repeat the observations of 1913 till the season of 1915.

OBSERVATIONS ON SOIL MOISTURE, COMPOSITION OF THE PLANT, AND NITRIC NITROGEN IN 1915

The weather conditions in 1913 were favorable for our experiments, but were scarcely more so than they usually are. We would say that it was a good year, perhaps a little more favorable than an

average one, but not enough so to cause comment. This was not the case with the season of 1915, which the consensus of opinion would unhesitatingly designate as a bad year for wheat, a wholly abnormal year. Mr. Robert Trimble, in charge of our meteorological observations, has furnished me the data for the months of April, May, June, July and August of the respective years, which show the differences between the seasons in so far as may be done by figures. The total rainfall during these months in 1913 was 6.77 inches, and in 1915, 13.37 inches. In 1913 we had only four wholly cloudy days during these months, while in 1915 we had only 57 days free enough from clouds to justify the designation of clear. In the following statements of mean temperatures that for 1913 is given first, and then that for 1915. April, 46.1°, 50.05°; May, 54.8°, 50.35°; June, 63.2°, 59.62°; July, 66.8°, 64.74°; August, 69.8°, 62.77°. The rainfall in 1915 was not only unusual, but it was distributed through the season so that the plants were kept wet most of the time, the prevalent cloudiness preventing a thorough external drying, even when there was no actual rainfall.

This proved to be very prejudicial, not only to my crop, but locally to all of our spring wheat, especially to our popular variety, the Defiance, because of the severe attack of rust which was induced by these conditions.

In 1913 I applied to my plots one acre-foot of water on 12 June and to four of them a second acre-foot on 12 July. Thirty-two of the plots received, as irrigating water and rainfall, practically 19 inches of water during the growing season, 12 inches of which was applied at one time and in clear weather. Three and one-half inches of the 6.8 inches of rain fell in April and May, and 2.5 inches between 13 and 24 July. This last period of rainfall caused some rust to develop. The subsequent fourteen days were dry and bright, and the damage was not serious. In 1915 the plots received from 0.5 to 0.6 of an acre-foot of irrigation water, this being all that was required to flood the land. It will be noticed that the amount of water received during the two seasons was very nearly the same. In 1915 the amount of rainfall was not only greater, but its distribution was different and accompanied by a great deal of cloudiness. These conditions affected not only the rate of the development of the plants and of the rust, but modified our conditions of soil moisture, the distribution of the nitrates, and probably also affected their formation, as well as the amount of fixation that took place. These last two factors are, unfortunately, not definitely known nor are they easily ascertained.

The general conditions as here described may seem to be unfortunate. As matters stand they really are, but were it not for the introduction of the factor of rust, I would be inclined to consider it

fortunate that our experiments were made during this season, for many facts, to be given subsequently, will tend to show, or perhaps prove, that the amount of water applied, be it as rainfall or irrigation, has comparatively little influence upon the composition of wheat.

It is very fortunate in this connection that we made three parallel series of experiments with three different varieties which differ in their susceptibility to injury by rust. If this had not been the case, if we had used only the Defiance in these experiments, we would not have been satisfied to abide by any results obtained. This variety was so badly shrunk that I could not sell it, except for chicken feed. The weight per bushel and the yield will indicate how badly it was injured, almost wholly, as I think, by the rust. The grain weighed from 47 to 53 pounds per bushel and the yield ranged from 10 to 23 bushels per acre. The other varieties were much better, both in weight per bushel and in yield per acre, though they also suffered from the effects of rust to some extent. The maximum yield, 41.5 bushels, weight per bushel 60 pounds, was obtained with Kubanka.

It may be well to state, in this connection, that the plants grown with the application of sodic nitrate seem more easily attacked by rust than those which are grown without it, and on this account tend to produce shrunk wheat. This, however, seems to be a specific effect of nitrates upon the wheat kernel as well as an effect of rust. This year the two acted together and produced, in the case of the Defiance, an almost total failure of the crop. This statement is made in this connection lest it should be thought that subsequent statements, pertaining to the effects of nitrates, did not make sufficient allowance for the effects of this parasite.

MOISTURE AND NITRIC NITROGEN IN THE SOIL, 1915

During this season, 1915, we took no samples to a greater depth than four feet, whereas in 1913 we took four series of samples to a depth of twelve feet. In 1913 we took 42 series in fallow and 18 series in cropped land to a depth of four feet. In 1915 we took 54 series in cropped and 6 series in fallow land to the depth of four feet. The moisture and nitric nitrogen were determined in all of these samples and the total nitrogen in twenty of the series. The dates on which our samples of 1915 were taken do not follow at regular intervals because of the frequent rains. We endeavored to allow a few days to elapse after a rain before we took the samples, but even with this precaution it is not probable that we have succeeded in making the samples altogether comparable with those of 1913.

The results obtained are given in the following tabular statements:

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 13 MAY, 1915

Depth	Section 1800, Fallow				Section 1700				Section 1800				Section 1900			
	Moisture		Nitric		Moisture		Nitric		Moisture		Nitric		Moisture		Nitric	
	Per cent	Parts per Million	Per cent	Parts per Million	Per cent	Parts per Million	Per cent	Parts per Million	Per cent	Parts per Million	Per cent	Parts per Million	Per cent	Parts per Million	Per cent	Parts per Million
Red Fife Plots—																
Top 3 inches	14.08	4.57		1.05	14.60		1.05		14.08		4.57		12.76		4.34	
4 to 7 inches	17.74	4.30		0.93	17.50		0.93		17.74		4.30		16.49		4.41	
8 to 12 inches	17.73	6.42		3.12	17.41		3.12		17.73		6.42		17.04		5.44	
13 to 24 inches	17.00	5.86		6.01	16.78		6.01		17.00		5.86		16.97		10.04	
25 to 36 inches	16.48	4.80		1.50	16.87		1.50		16.48		4.80		16.92		3.80	
37 to 48 inches	15.74	2.84		1.66	16.35		1.66		15.74		2.84		16.32		1.74	
Kubanka Plots—																
Top 3 inches			12.07	4.19			4.19		12.53		4.21		13.93		5.08	
4 to 7 inches			16.81	4.01			4.01		17.17		4.44		17.38		5.30	
8 to 12 inches			16.85	6.52			6.52		16.99		5.69		16.72		4.42	
13 to 24 inches			15.85	9.66			9.66		16.67		7.34		16.91		7.77	
25 to 36 inches			16.10	5.22			5.22		16.54		4.41		16.51		5.24	
37 to 48 inches			16.77	2.75			2.75		17.07		2.76		16.28		2.32	

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 18 JUNE, 1915

Red Fife Plots—								
Top 3 inches	13.32	5.45	9.08	1.80	9.20	1.45	8.33	1.21
4 to 7 inches	17.44	4.46	12.82	1.27	12.76	1.19	12.52	0.79
8 to 12 inches	16.61	2.50	13.45	1.49	12.93	1.01	14.11	0.89
13 to 24 inches	16.77	2.00	14.27	1.22	14.74	0.65	13.67	0.80
25 to 36 inches	16.57	4.24	14.32	0.97	14.59	1.47	13.99	0.80
37 to 48 inches	16.05	3.64	14.75	0.97	13.97	1.38	14.65	0.81
Kubanka Plots—								
Top 3 inches			10.45	2.56	10.20	1.39	10.59	1.55
4 to 7 inches			14.14	1.38	13.71	1.37	13.60	1.60
8 to 12 inches			13.63	1.21	13.52	1.45	13.97	1.61
13 to 24 inches			13.72	1.21	13.79	0.80	13.83	1.53
25 to 36 inches			14.52	3.66	14.03	1.46	13.70	3.54
37 to 48 inches			16.15	2.15	14.65	1.38	13.35	1.92

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 8 JULY, 1915

Depth	Section 1800, Fallow			Section 1700			Section 1800			Section 1900			
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	
Red Fife Plots—													
Top 3 inches	12.93	6.86	14.13	1.54	14.60	1.05	14.51	1.30					
4 to 7 inches	17.48	3.36	14.95	1.31	15.56	0.82	15.89	1.40					
8 to 12 inches	17.48	3.36	15.40	1.76	15.82	1.40	15.81	1.65					
13 to 24 inches	16.97	1.92	15.30	1.02	16.04	1.16	15.27	1.63					
25 to 36 inches	16.64	2.25	15.27	0.82	15.74	0.90	14.33	0.98					
37 to 48 inches	16.07	2.56	14.20	0.81	15.80	0.82	15.04	0.49					
Kubanka Plots—													
Top 3 inches			13.23	1.20	15.46	0.74	14.61	0.77					
4 to 7 inches			15.02	0.81	16.06	1.07	16.17	1.16					
8 to 12 inches			14.48	1.22	16.01	0.91	16.55	1.33					
13 to 24 inches			14.80	0.81	15.73	0.66	16.30	0.83					
25 to 36 inches			15.44	0.41	15.96	0.33	15.96	0.66					
37 to 48 inches			16.62	0.16	16.18	0.25	17.19	0.42					

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 3 AUGUST, 1915

Red Fife Plots—												
Top 3 inches	11.37	8.66	12.47	12.47	1.58	12.31	12.09	0.71	12.09	1.25	12.09	1.25
4 to 7 inches	15.65	5.89	12.14	12.14	1.11	11.56	12.06	1.88	12.06	0.83	12.06	0.83
8 to 12 inches	16.06	4.72	11.11	11.11	1.29	11.21	11.18	1.02	11.18	0.86	11.18	0.86
13 to 24 inches	16.06	2.11	10.75	10.75	0.85	12.13	11.96	1.22	11.96	0.78	11.96	0.78
25 to 36 inches	15.38	1.72	12.32	12.32	0.95	12.75	12.72	0.79	12.72	0.56	12.72	0.56
37 to 48 inches	15.44	1.93	12.97	12.97	0.69	13.18	12.96	0.69	12.96	0.00	12.96	0.00
Kubanka Plots—												
Top 3 inches			11.83	11.83	0.98	12.59	12.83	0.79	12.83	0.64	12.83	0.64
4 to 7 inches			11.23	11.23	0.86	12.51	12.40	1.11	12.40	0.47	12.40	0.47
8 to 12 inches			10.28	10.28	0.85	11.45	11.87	0.55	11.87	0.47	11.87	0.47
13 to 24 inches			10.03	10.03	0.54	11.59	12.19	0.55	12.19	0.55	12.19	0.55
25 to 36 inches			11.44	11.44	0.31	12.46	12.98	0.39	12.98	0.40	12.98	0.40
37 to 48 inches			13.97	13.97	0.08	13.49	13.68	0.40	13.68	0.16	13.68	0.16

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 30 AUGUST, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	9.14	2.15	12.30	2.22	11.98	2.44	12.74	2.87
4 to 7 inches	12.64	1.59	12.16	1.82	12.76	1.75	13.65	2.41
8 to 12 inches	12.68	1.91	10.85	1.25	10.72	1.40	11.05	1.41
13 to 24 inches	14.18	1.54	10.78	1.71	10.81	1.01	11.45	0.78
25 to 36 inches	13.95	0.73	12.36	0.48	12.16	0.87	12.24	0.23
37 to 48 inches	14.16	2.19	12.88	0.24	12.71	0.64	12.62	0.32
Kubanka Plots—								
Top 3 inches			10.62	2.18	10.22	2.09	12.21	2.45
4 to 7 inches			12.04	1.50	13.68	1.49	14.28	2.11
8 to 12 inches			10.18	1.47	10.91	1.17	11.58	1.57
13 to 24 inches			9.62	0.84	10.89	1.25	12.03	0.94
25 to 36 inches			11.29	0.86	11.71	0.78	13.06	0.96
37 to 48 inches			12.85	0.64	12.56	0.72	13.64	0.80

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 14 SEPTEMBER, 1915

Red Fife Plots—												
Top 3 inches	10.08	4.79	12.60	5.70	3.85	11.62	11.90	5.76	11.90	5.76	11.90	5.76
4 to 7 inches	12.54	2.62	13.22	3.11	3.02	12.75	13.56	3.45	13.56	3.45	13.56	3.45
8 to 12 inches	13.40	3.29	12.01	2.05	1.95	11.09	12.01	2.21	12.01	2.21	12.01	2.21
13 to 24 inches	13.99	2.02	11.26	1.17	1.41	11.25	12.08	1.50	12.08	1.50	12.08	1.50
25 to 36 inches	13.81	1.93	12.28	0.87	0.95	12.32	12.41	1.03	12.41	1.03	12.41	1.03
37 to 48 inches	13.63	1.85	12.93	0.87	0.87	12.30	15.75	0.82	15.75	0.82	15.75	0.82
Kubanka Plots—												
Top 3 inches			10.38	3.25	2.78	12.47	12.68	4.85	12.68	4.85	12.68	4.85
4 to 7 inches			12.93	1.59	2.02	14.18	15.10	2.53	15.10	2.53	15.10	2.53
8 to 12 inches			11.30	1.25	1.26	12.08	12.44	1.27	12.44	1.27	12.44	1.27
13 to 24 inches			10.81	0.70	0.47	11.09	11.98	1.10	11.98	1.10	11.98	1.10
25 to 36 inches			12.74	0.24	0.39	12.17	12.93	0.78	12.93	0.78	12.93	0.78
37 to 48 inches			14.38	0.00	0.16	13.43	13.31	0.40	13.31	0.40	13.31	0.40

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 28 SEPTEMBER, 1915

Depth	Section 1800, Fallow			Section 1700			Section 1800			Section 1900		
	Moisture Per cent	Nitric Nitrogen Parts per Million	Depth	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	
Red Fife Plots—												
Top 3 inches	16.86	2.50		17.91	2.96	17.90	2.54	17.75	3.38			
4 to 7 inches	15.91	5.70		16.40	4.65	16.84	4.76	16.96	6.69			
8 to 12 inches	13.37	1.60		12.93	1.75	12.39	1.98	11.62	1.73			
13 to 24 inches	14.14	1.21		11.30	0.78	11.53	0.78	11.14	0.86			
25 to 36 inches	14.08	1.13		12.50	0.56	12.29	0.47	11.20	0.39			
37 to 48 inches	13.52	1.60		12.77	0.24	13.11	0.24	11.32	0.00			
Kubanka Plots—												
Top 3 inches				15.98	3.80	16.91	3.25	17.17	3.44			
4 to 7 inches				16.00	4.30	15.99	4.05	16.77	4.59			
8 to 12 inches				11.38	1.80	13.36	1.92	14.45	1.95			
13 to 24 inches				10.92	0.78	11.69	0.71	13.07	0.48			
25 to 36 inches				12.88	0.40	12.56	0.40	13.53	0.48			
37 to 48 inches				14.36	0.32	13.43	0.32	13.87	0.08			

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 25 OCTOBER, 1915

Red Fife Plots—												
Top 3 inches	No separate samples			14.82	2.09		15.16	1.80		14.84	3.34	
4 to 7 inches	taken, same as			17.05	2.26		17.43	1.93		17.08	5.03	
8 to 12 inches	Section 1800			16.72	2.88		16.88	3.51		16.72	3.84	
13 to 24 inches				16.05	1.90		16.25	2.16		16.51	2.99	
25 to 36 inches				15.12	0.41		14.92	0.98		14.36	0.81	
37 to 48 inches				13.78	0.32		13.56	0.56		13.19	0.64	
Kubanka Plots—												
Top 3 inches				13.68	2.26		14.88	1.71		14.67	1.71	
4 to 7 inches				16.98	3.01		17.37	1.85		17.16	1.51	
8 to 12 inches				16.39	3.82		17.35	2.60		16.91	2.50	
13 to 24 inches				15.72	1.73		16.38	2.08		16.66	1.92	
25 to 36 inches				14.65	0.57		15.49	0.58		15.51	0.50	
37 to 48 inches				15.06	0.49		14.48	0.57		14.64	0.25	

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 22 NOVEMBER, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	No samples taken		10.97	2.73	11.81	3.70	11.99	3.16
4 to 7 inches			15.29	2.05	14.96	3.43	15.37	3.95
8 to 12 inches			15.60	2.54	15.52	3.95	15.44	2.30
13 to 24 inches			15.50	2.14	15.40	2.54	15.65	1.81
25 to 36 inches			14.52	0.49	14.15	0.80	14.40	0.49
37 to 48 inches		13.58	0.16	13.90	0.57	12.94	0.32	
Kubanka Plots—								
Top 3 inches	No samples taken		10.60	2.48	8.83	2.58	12.14	2.68
4 to 7 inches			14.70	3.26	15.34	2.45	15.36	4.59
8 to 12 inches			15.26	2.53	15.00	3.93	16.26	3.32
13 to 24 inches			14.69	1.95	15.19	2.21	15.58	2.63
25 to 36 inches			13.99	0.57	14.34	0.88	14.85	0.89
37 to 48 inches		15.17	0.66	13.89	0.24	14.43	0.88	

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 13 DECEMBER, 1915

Red Fife Plots—							
Top 3 inches	11.21	4.31	8.78	4.35	10.46	5.90	
4 to 7 inches	15.42	3.87	14.61	3.83	14.86	5.06	
8 to 12 inches	15.78	4.46	15.94	4.63	15.62	4.69	
13 to 24 inches	15.52	2.97	15.16	3.52	15.62	2.72	
25 to 36 inches	14.15	2.03	14.18	2.19	11.38	1.42	
37 to 48 inches	13.78	1.46	13.65	2.26	14.44	1.14	
Kubanka Plots—							
Top 3 inches	10.51	4.51	10.78	4.37	10.91	4.76	
4 to 7 inches	15.20	3.77	15.34	3.11	15.62	3.79	
8 to 12 inches	15.36	3.78	15.93	3.56	16.05	4.31	
13 to 24 inches	14.37	3.25	15.52	3.20	15.60	3.79	
25 to 36 inches	13.37	1.77	14.74	2.21	14.57	1.91	
37 to 48 inches	14.40	1.71	14.46	1.47	14.30	1.66	

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 16 FEBRUARY, 1916

Depth	Section 1800		Depth	Section 1800	
	Moisture percent	Nitric Nitrogen Parts per Million		Moisture percent	Nitric Nitrogen Parts per Million
Red Fife Plots—			Kubanka Plots—		
Top 3 inches.....	16.108	4.63	Top 3 inches.....	15.083	5.57
4 to 7 inches.....	16.607	4.10	4 to 7 inches.....	16.450	4.71
8 to 12 inches.....	16.717	4.34	8 to 12 inches.....	16.944	5.50
13 to 24 inches.....	15.834	2.46	13 to 24 inches.....	15.210	1.73
25 to 36 inches.....	12.947	0.70	25 to 36 inches.....	13.589	0.80
37 to 48 inches.....	13.492	0.64	37 to 48 inches.....	14.075	0.64

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 22 MARCH, 1916

Depth	Section 1700		Depth	Section 1800		Section 1900	
	Moisture Percent	Nitric Nitrogen Parts per Million		Moisture Percent	Nitric Nitrogen Parts per Million	Moisture Percent	Nitric Nitrogen Parts per Million
Red Fife Plots—			Kubanka Plots—				
Top 3 inches.....	9.774	4.59	Top 3 inches.....	8.931	5.35	9.145	6.12
4 to 7 inches.....	16.234	4.63	4 to 7 inches.....	18.456	4.07	15.549	4.67
8 to 12 inches.....	14.488	3.70	8 to 12 inches.....	15.056	3.12	15.010	3.51
13 to 24 inches.....	15.095	1.64	13 to 24 inches.....	15.369	1.88	15.621	1.97
25 to 36 inches.....	13.764	0.88	25 to 36 inches.....	13.853	0.88	14.515	0.65
37 to 48 inches.....	13.367	0.64	37 to 48 inches.....	13.465	0.64	14.238	0.32
Kubanka Plots—							
Top 3 inches.....	12.611	6.02	Top 3 inches.....	9.608	7.19	9.429	5.35
4 to 7 inches.....	16.096	4.38	4 to 7 inches.....	15.394	4.34	16.392	4.46
8 to 12 inches.....	15.357	3.61	8 to 12 inches.....	15.850	3.61	16.260	3.14
13 to 24 inches.....	14.587	2.11	13 to 24 inches.....	15.456	2.12	15.593	1.64
25 to 36 inches.....	13.588	1.21	25 to 36 inches.....	13.929	0.88	14.649	0.65
37 to 48 inches.....	14.602	0.65	37 to 48 inches.....	13.636	0.24	14.057	0.57

We took no samples for the determinations of moisture and nitric nitrogen in January because the weather was unfavorable and the ground frozen. We took only two series of samples in February, i.e. on the 16th of the month when we found the ground frozen to a depth of six inches. A comparison of the results obtained for the samples taken 13 December, 1915, with those obtained for the same section in February and again in March, 1916, shows that the distribution of the nitric nitrogen had changed during the interval between 13 December, 1915 and 16 February, 1916, but had remained essentially the same from 16 February to 22 March, 1916. These differences in the distribution are most marked in the third and fourth foot. Concerning the total amount present in the soil, there is in every case less in the second, third and fourth foot, in the two last series of samples taken, than in those taken 13 December, 1915, but more than in those taken 22 November, 1915. The surface foot shows an increase but it is not sufficient to balance the loss in the bottom three feet.

CONCERNING THE DISTRIBUTION OF MOISTURE

The rainfall in 1913 was only 6.77 inches during the growing season and this fell during two periods, the first from 9 to 20 May and the second from 13 to 23 July, with almost no cloudy weather. In 1915 we had 13.47 inches rainfall distributed rather evenly throughout the corresponding period. In July, we had only 2.12 inches rainfall, but this was distributed over eleven days and a "trace" is recorded on five days. Only eleven days during the month are recorded as clear. In 1913, we had a greater rainfall during this month, but its distribution was different and the cloudiness was very much less; there was only one day designated as wholly cloudy. The moisture in the soil, as shown by our samples, was much more clearly alike during the two seasons than one would expect, taking the very different weather conditions into consideration. But it must be remembered that we allowed a few days to elapse after a rain before we took our soil samples. These samples, except those designated fallow, were taken from cropped land. Determinations of moisture in the surface samples immediately after a rain would have had no object whatever for our purposes. A comparison of the tables given for 1913, in Part I (Bulletin 208), with those given for 1915 in the preceding pages, will show no regularity in the differences, which are much less than we would expect, two percent being about the maximum.

I deem it almost useless to state that the time of the rainfall, the cloudiness and temperature are much more important than the amount of the rainfall. Every farmer in the extreme eastern states is aware of this, for a few warm, foggy days with no rainfall may ruin the most flattering prospects for a wheat crop. Warm, cloudy weather, with but little wind and enough rain to keep the plants wet

for a few days at the critical period in the development of the wheat may ruin the crop. It is in this manner that moisture enters into our problem of producing a crop rather than as a soil problem, provided that there is not at any time a decided deficiency in the soil. The moisture in these experimental plots for the two years 1913 and 1915 varied from approximately 12 to 17 percent, except at periods of irrigation or rainfall.

An excessive amount of water in the soil might drown the plants or it might dilute the nutrients in the soil, or even wash them out to such an extent as to be detrimental. We have no proof in the data so far obtained that the latter is the case to such an extent that we should give it any consideration in this place.

The distribution of the nitrates in the soil, particularly in the top two feet, is very largely determined by the water received at the surface. We endeavored in 1913 to follow this effect to a depth of 12 feet.*

At the end of April, we found the distribution of the nitrates in the soil taken to 12 feet very varying, but the nitrates were quite abundant within this depth. The application of one foot of water at one time sufficed to move the most of the nitrates to a greater depth. The frequent light rains of 1915 effected a different distribution of the nitrates in the top two feet of the soil from that which we had in 1913. I do not think that this was any disadvantage to the 1915 crop. It may have, and probably did, change the point of most active feeding within this depth, but was probably without further effect. In 1913 the surface foot was markedly the richest area; in 1915 the nitrates were more evenly divided between the top two feet.

The total amount of the nitric nitrogen present in the four feet of soil sampled during the two seasons is much more nearly uniform than we would expect to find it. There are such variations as we know to prevail in different sections taken on the same date. These variations are often relatively large both for any given foot, and also for samples representing from four to twelve feet. We have a few samples taken to a depth of four feet which are comparable, as they were taken from the same plots. On 14 July, 1913, we found nitric nitrogen equivalent to 260.3 pounds of sodic nitrate, and in another sample, 277.3 pounds; on the same date 1915, we found 273.2 pounds per acre.

The effect of the growing crop upon the amount of nitric nitrogen in the soil is very clearly shown during both seasons. The following data are obtained from the same plot of ground fallow and occupied by wheat: On 14 July, 1913, nitric nitrogen in the top four feet of fallow ground was equal to 260.36 pounds sodic nitrate, and in the cropped land to 120.36 pounds; on 8 July, 1915, it

* Part I (Colorado Exp. Sta. Bulletin 208), pp. 14 and 15.

was equal to 263.2 and 91.6 pounds, respectively.

Lyon and Bizzell of Cornell University have shown that the nitrifying efficiency of soil occupied by wheat is depressed, and this may account for a part of the difference.* But the results, taken as they stand, show a very decided difference between the fallow ground and that occupied by the plants. An examination of the 160 series of samples taken shows this to be uniformly the case, but in varying degrees.

This suppression of the nitrates, be it due to the utilization of the nitric nitrogen or the suppression of the nitrifying efficiency of the soil or to both, is certainly only a temporary result, for as soon as the wheat has ripened, the production of nitrates goes on rapidly, as the following results summarized from the data previously given shows. The equivalent sodic nitrate is given for the four feet sampled:

		TOTAL SODIC NITRATE, FOUR-FOOT SECTIONS OF SOIL†			
		1913		1915	
		Section 1800	Section 1900	Section 1800	Section 1900
12 May	Fife	459.7	340.6	440.4	489.6
1 Aug.	Fife	114.0	107.8	91.9	51.7
30 Aug.	Fife	....	....	102.7	80.3
22 Nov.	Fife	....	....	179.0	136.3
13 May	Kubanka	333.2	213.3	465.8	485.0
1 Aug.	Kubanka	155.9	81.4	51.4	38.9
30 Aug.	Kubanka	....	....	102.2	112.1
22 Nov.	Kubanka	....	....	154.3	191.6

† The results have been calculated as sodic nitrate.

The plants had not developed enough by 12 May in either year to make much difference between these plots and fallow ground. The figures given for 1 August, however, are really not altogether comparable, because in 1913 the plants were practically ripe on this date, but were two weeks later in 1915, so that the data for 30 August, 1915, are much more nearly comparable with those of 1 August, 1913, than are those of 1 August, 1915. In either case we see that a very large amount of nitrogen has disappeared. The irrigation may have washed out a large percentage of it, as we found in 1913 that the application of one foot of water sufficed to remove the larger part of the nitrates to a greater depth than 12 feet. That the irrigation did not make the difference in 1915 is indicated by the results obtained on a fallow plot used as a check. (See the tables for 18 June and 8 July.) The land was irrigated 12 June, but owing to the already abundant supply of moisture in the soil, this plot received only 0.60 of an acre-foot, which did not suffice to do much if any leaching. We are forced, I think, to attribute the depression of the nitrates to the action of the plants, either by inhibiting the formation of the nitrates or by using them up. The wheat

* Journal of the Franklin Institute, Jan. and Feb. 1911, p. 220.

on the plots that did not receive an application of the sodic nitrate did not indicate an excessive supply of these salts, nor did it show any deficiency, so far as growth and color of the plant may be depended upon as criteria for our judgment. As soon as the crop was removed the accumulation of nitric nitrogen took place rapidly and the ground was comparable to fallow land, especially as I had it double disced and there was at all times an adequate supply of moisture. The cropped plots had very nearly overtaken the fallowed check by the end of September. The rate of increase in the nitric nitrogen or its equivalent amount of sodic nitrate is clearly shown in the table just given, from which we see that we have a maximum increase of about five-fold from 38.9 to 191.6 pounds of sodic nitrate between 1 August and 22 November.

In my preceding statements concerning the nitric nitrogen, I have assumed that a glance at the tables given would suffice to make this subject clear, but it may be well to present it in another manner. In the following table I have converted the nitric nitrogen into its equivalent amount of sodic nitrate, and given the amount found in the first foot and that in the succeeding three feet. We did not continue the taking of our samples later than 1 August in 1913, for we harvested a few days (4 to 6) later, but in 1915 we continued the taking of samples till 13 December.

DISTRIBUTION OF NITRATES IN THE FIRST FOOT AND THE SUCCEEDING THREE FEET OF SOIL IN 1913 AND 1915

Date	Variety of Wheat	Section	First Foot	Succeeding Three Feet
12 May 1913	Red Fife	1800	254.2	205.4
13 May 1915	Red Fife	1800	124.4	316.0
12 May 1913	Red Fife	1900	150.1	190.6
13 May 1915	Red Fife	1900	115.7	373.9
1 Aug. 1913	Red Fife	1800	71.8	42.3
3 Aug. 1915	Red Fife	1800	29.3	62.6
1 Aug. 1913	Red Fife	1900	62.0	45.8
3 Aug. 1915	Red Fife	1900	19.5	32.2
30 Aug. 1915	Red Fife	1800	42.2	60.5
30 Aug. 1915	Red Fife	1900	50.6	29.7
22 Nov. 1915	Red Fife	1800	89.1	89.1
22 Nov. 1915	Red Fife	1900	73.6	62.8
14 Dec. 1915	Red Fife	1800	103.1	191.3
14 Dec. 1915	Red Fife	1900	121.8	118.7
12 May 1913	Kubanka	1800	186.1	147.0
13 May 1915	Kubanka	1800	117.7	348.1
12 May 1915	Kubanka	1900	142.0	71.4
13 May 1915	Kubanka	1900	117.1	367.9
1 Aug. 1913	Kubanka	1800	94.7	61.2
3 Aug. 1915	Kubanka	1800	19.3	32.5
1 Aug. 1913	Kubanka	1900	49.0	32.4
3 Aug. 1915	Kubanka	1900	12.3	26.6
30 Aug. 1915	Kubanka	1800	36.2	66.0
30 Aug. 1915	Kubanka	1900	47.3	64.8
22 Nov. 1915	Kubanka	1800	74.4	80.0
22 Nov. 1915	Kubanka	1900	86.0	105.6
14 Dec. 1915	Kubanka	1800	86.7	164.8
14 Dec. 1915	Kubanka	1900	104.1	176.64

It will be noticed that in 1913 the first foot of soil usually contained more nitrates than the succeeding three feet, except on 12 May, whereas this is not true to the same extent in 1915. In other words, the frequent rains of 1915 caused the nitrates to pass below the first foot. This was not due to the difference in the amount of water received during the months considered, for that was approximately the same during the respective seasons, about 19 inches, nor was it due to differences in soil, for we used the same plots, nor to the wheat, for we used the same varieties, but to the distribution of the water applied to the surface throughout the season.

THE TOTAL NITROGEN

On 27 June, 1913, we sampled three sections of soil to a depth of eleven feet, making a separate sample of each foot of the section. These samples agreed in showing that the surface foot contained, roughly, twice as much nitrogen as the second, and the second twice as much as the third, but from the third downward, including the eleventh foot, the amount of the total nitrogen remained fairly constant, at about 0.02 percent. In such four-foot samples, we took during this season of 1913, six sets of them, the same fact was shown, i. e., that the total nitrogen in the fourth foot was about 0.02 percent, or between this and 0.03 percent. These samples were taken from fallow land, but six sets taken from the cropped land showed essentially the same thing. We cannot say that the samples as taken showed any regular differences in the nitrogen in the first, or any succeeding foot in favor of the fallow land which would justify any attempt to interpret them.

In 1915 we determined the total nitrogen in 19 series of samples taken to a depth of four feet. These agree in showing that the total nitrogen falls to an amount equal to from 0.02 to 0.03 percent in the fourth foot. The samples taken 13 May, before the plants had attained any considerable development, showed that the surface foot was perceptibly richer in total nitrogen than on the two subsequent dates, 1 September and 25 October, when these determinations were repeated. The same fact holds to even a greater extent for the nitric nitrogen, as the table last given shows for the corresponding nitrates. Of course, we have in this question the two serious difficulties which confront us in this work, i. e., the difficulty of obtaining samples which are comparable even when taken from as nearly the same spot as possible without seeking the identical spot where we made the preceding boring, and the further question in regard to the importance that we are justified in attaching to a few ten-thousandths or even thousandths of one percent. There can be no question but that differences as small as, or even smaller than, thousandths of one percent, not only may, but are, of significance in these problems. If any question be entertained on

this point, we have only to consider the results produced by the addition of 40 pounds of nitrogen to the acre, an amount equal to 0.001 percent calculated on a foot of soil. The application of this amount at the time of seeding, and harrowed in to a depth of three inches, suffices to change the growth of the crop and the character of the wheat. In determining the total nitrogen we involve all of the nitric nitrogen that may be present and other unstable forms to such an extent that the differences obtained in our analyses are difficult, if not impossible, of interpretation with any degree of certainty. We have, for instance, on 13 May, 1915, in Section 1800, Fife, a total of 5,305 pounds of nitrogen in the surface acre-foot; on 1 September in the same land cropped to wheat, 4,350, and in a check plot kept fallow, 4,684 pounds. We have for this land a loss of 625 pounds of nitrogen for the surface acre-foot between 13 May and 1 September. This is without the crop, but with the crop of wheat we have a further loss of 334 pounds. Some of this may have been washed below the depth to which we took our samples and this may have been lost. There are too many undetermined factors at play in this question to permit us to interpret our results. There have been, without doubt, both gains and losses, some of the latter due to the crop, but just to what extent we do not know. It seems very improbable that the loss of 334 pounds of nitrogen, noted above, is due directly to the crop, which did not remove, as a mature crop, more than a sixth or, at most, a fifth of this amount. The crop of grain removed was 33 bushels per acre and the straw weighed 4,750 pounds, which, together, would not remove a fifth of this deficit, 334 pounds. The analytical results themselves are as good as can be gotten; this is not the trouble, but other difficulties inherent in the problem.

PERCENTAGE OF TOTAL NITROGEN IN SOIL OF WHEAT PLOTS—SEASON 1915

Date	Depth	Section	Section	Section	Section	Section	Section	Section
		1700	1800	1900	1700	1800	1900	1800
		Fife	Fife	Fife	Kubanka	Kubanka	Kubanka	Fallow
13 May	Top 3 inches	.1393	.1279	.1331	.1368	.1327	.1373	Not
	4 to 7 inches	.1441	.1403	.1382	.1421	.1385	.1439	sampled
	8 to 12 inches	.1322	.1293	.1316	.1212	.1315	.1328	Same as
	13 to 24 inches	.0718	.0645	.0737	.0669	.0700	.0711	Section
	25 to 36 inches	.0351	.0349	.0477	.0339	.0383	.0374	1800
	37 to 48 inches	.0332	.0277	.0295	.0289	.0273	.0287	Fife
1 Sept.	Top 3 inches	.1205	.1113	.1243	.1198	.1239	.1260	.1202
	4 to 7 inches	.1251	.1123	.1208	.1218	.1224	.1282	.1226
	8 to 12 inches	.1045	.1044	.0984	.1130	.0994	.1046	.1108
	13 to 24 inches	.0561	.0506	.0578	.0523	.0562	.0553	.0551
	25 to 36 inches	.0297	.0274	.0332	.0294	.0338	.0292	.0295
	37 to 48 inches	.0190	.0175	.0214	.0245	.0244	.0247	.0224
25 Oct.	Top 3 inches	.1274	.1196	.1241	.1224	.1193	.1255	
	4 to 7 inches	.1157	.1263	.1292	.1307	.1145	.1108	Not
	8 to 12 inches	.0985	.0979	.0901	.0915	.1102	.1004	sampled
	13 to 24 inches	.0530	.0506	.0549	.0494	.0441	.0517	
	25 to 36 inches	.0327	.0275	.0341	.0305	.0353	.0308	
	37 to 48 inches	.0240	.0223	.0253	.0227	.0233	.0226	

The results of 1915 agree very closely with those obtained in 1913 showing that the total nitrogen falls, practically, to a constant at a depth of three feet. This was not the case with the nitric nitrogen, as is shown by the samples taken 29 April, 1913, to a depth of 12 feet. The distribution of nitric nitrogen in these was very erratic. (See Part I (Colorado Bulletin 208) p. 20). It is quite common in our samples to find that the fourth foot contains less than one-tenth as much nitric nitrogen as the first foot, but it may contain as much or more, or again it may contain no nitric nitrogen.

It has been intimated that we have considered the difficulty in obtaining samples on different dates, that would have been the same, had the samples been taken on the same date. This difficulty is real and is well shown by the results obtained with 150 samples taken from as many contiguous square feet. These results are given in Part I (Colorado Bulletin 208) p. 26, where we find a difference of 354 pounds of nitrogen in the surface foot. This difference is even larger than that found for the plot sampled on 13 May and 1 September, 1915, before and after the crop had been grown. This difficulty is not to be avoided in the case of field experiments. Recourse must be had to other methods of experimentation which was contemplated from the beginning of this work.

We have now given the weather conditions, the moisture in the soil, the nitric and total nitrogen in the soil for 1915, and compared these factors with the results for 1913. The two seasons were wholly unlike; the principal differences were that the temperature in 1915 was lower, and there was about twice the amount of rainfall. Its distribution was much more general than in 1913, when over two-thirds of the total for the growing season, 6.77 inches, fell in May and July. In 1913 the rainfall for July was confined to a period of not more than 12 days, including several on which either no rain or only a very small amount fell. The total water, rainfall and irrigation, received during the two seasons, was essentially the same, about 19 inches. The moisture in the soil samples taken in 1915 was a little higher, the average being between one and two percent. The effects of these weather conditions on the amount of the nitrates in fallow land, taken to a depth of four feet, were small. The maximum difference was equivalent to 13 pounds of sodic nitrate in the top four feet. The more even distribution of the water received by the land in 1915 brought about a different distribution of the nitrates, but we have no proof that they were removed beyond the feeding area of the plants, which we assume may extend in this soil, to a depth of four feet. There is no indication that the dilution of the nitrates in the soil was such as to affect in any way the growth of the crop. This last statement does not include any reference to the composition of the crop.

The total nitrogen is slightly higher in 1915 than in 1913. While this is subject to variation, due to the difficulties of sampling, it is true of so many samples that we may perhaps give it some weight even though the differences are very small. The soil conditions vary less in the two seasons than the weather conditions led me to expect.

THE EFFECTS OF INDIVIDUAL FERTILIZERS UPON THE GROWTH OF THE PLANTS

In Part I (Bulletin 208), p. 31, et seq., we stated that we could not discern any differences in the growth and ripening of the plants on the various plots, except on those that had received a dressing of sodic nitrate. The smallest amount of this salt applied, equal to 40 pounds of nitrogen, sufficed to produce a very marked difference in the color, growth, and tendency of the plants to lodge. The tendency to lodge varied considerably in the different varieties of wheat used. The Defiance seemed most susceptible. We would not be justified in asserting that 40 pounds of nitrogen per acre produced as serious results as 120 pounds, still it was enough to cause the plants to show its effects just as sharply as the 120 pounds, and to cause the wheat to lodge very badly, the plants to rust, and to produce, even when not attacked by rust, shrunken wheat. The results in 1915 were of the same character as in 1913, but owing to the frequent, light rains and the very luxuriant growth of the plants, the lodging and rusting were worse than in 1913. The yield of the Defiance on the plots that were dressed with sodic nitrate ranged from 9 to 13 bushels of very badly shrunken wheat. The wheat of this variety, Defiance, was all badly shrunken in 1915, but the plots which had received an application of sodic nitrate produced much poorer grain than the others; it was so badly shrunken that it could scarcely be considered grain at all. There can be no question but that the sodic nitrate tends to produce shrunken wheat, but in both 1914 and 1915 the most important cause was rust on the plants.

The following data will enable the reader to judge of the effects of the various fertilizers upon the development of the plant as grown under our conditions. The following table gives a sort of correlation of these effects:

EFFECTS OF FERTILIZERS UPON THE DEVELOPMENT OF PLANTS* 1914

		DEFIANCE				RED FIFE				KUBANKA			
Fertilizer per acre		Average height in inches	Average length of heads in inches	Average number of spikelets	Average number of kernels per spikelet	Average height in inches	Average length of heads in inches	Average number of spikelets	Average number of kernels per spikelet	Average height in inches	Average length of heads in inches	Average number of spikelets	Average number of kernels per spikelet
Section 1700													
120 pounds Nitrogen	.....	52.1	4.49	19.8	2.20	51.4	3.93	16.2	2.10	59.6	2.78	18.0	2.67
60 pounds Phosphorus	.....	50.9	3.99	18.1	2.56	52.1	3.74	15.6	1.80	56.8	2.61	16.5	2.62
200 pounds Potassium	.....	48.0	3.96	18.3	2.50	50.4	3.70	15.3	..	55.3	2.58	16.1	2.48
None	.....	48.7	4.07	18.5	2.31	52.2	3.80	15.5	..	56.5	2.66	16.7	2.50
Section 1800													
80 pounds Nitrogen	.....	51.5	4.34	19.5	2.26	54.1	3.90	16.4	2.21	59.8	2.68	18.0	2.62
40 pounds Phosphorus	.....	52.1	4.09	18.9	2.44	50.6	3.60	15.1	1.80	61.6	2.50	16.7	2.98
150 pounds Potassium	.....	50.4	3.90	18.0	2.44	48.3	3.60	15.1	1.90	53.9	2.50	16.2	2.42
None	.....	52.2	4.06	18.7	2.32	49.6	3.60	14.8	..	57.0	2.54	16.6	2.73
Section 1900													
40 pounds Nitrogen	.....	54.8	4.28	19.0	2.35	56.2	3.85	16.3	2.00	57.4	2.64	17.0	2.11
20 pounds Phosphorus	.....	52.1	4.18	19.0	2.39	50.3	3.67	15.5	..	55.9	2.55	16.5	2.27
100 pounds Potassium	.....	50.6	3.79	17.1	2.46	50.2	3.50	14.6	1.80	49.3	2.49	15.5	2.45
None	.....	56.1	3.88	18.0	2.51	51.1	3.60	14.8	..	58.1	2.50	16.4	2.28

* Averages are based on 100 plants taken without selection

It appears from this table that the shortest plants, with the shortest heads, were produced on the plots receiving potassium. The lowest average kernels per spikelet is found for those plots to which nitrates had been applied, but we find here the highest average for the length of head. This last is the only feature that holds throughout the table and this is not very pronounced. This table shows that the effects of the fertilizers given are neither great nor uniform, even in the small effects produced. We might infer from the effect of the nitrates that an excessive food-supply lessens fecundity.

RATIO OF THE STEMS, LEAVES AND HEADS IN THE GREEN PLANTS

The following table, which gives the relative green weights of the stems, leaves and heads for the plants grown with the different fertilizers, shows a few differences in these ratios, but they are not constant. The figures are based upon 2,000-gram samples and the loss represents the waste in preparing and cutting them, including the evaporation that took place. This was often very considerable, especially if the plants were wet, due to external moisture, which was often the case and unavoidable, as we had to cut the samples in the morning in order to handle them the same day.

RATIO OF GREEN WEIGHTS OF STEMS, LEAVES AND HEADS OF RED FIFE, 1915

Date	Fertilizer	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	67.38	19.50	12.03
13 July	Phosphorus, 60 pounds	68.45	16.25	12.80
13 July	Potassium, 200 pounds	67.46	14.34	13.96
13 July	None	69.86	15.90	12.41
23 July	Nitrogen, 120 pounds	70.00	9.25	20.15
23 July	Phosphorus, 60 pounds	66.85	7.40	24.00
23 July	Potassium, 200 pounds	65.75	6.75	26.50
23 July	None	68.85	8.85	21.40
6 Aug.	Nitrogen, 120 pounds	69.25	....	30.25
6 Aug.	Phosphorus, 60 pounds	62.10	....	36.85
6 Aug.	Potassium, 200 pounds	61.10	....	38.85
6 Aug.	None	63.00	....	35.35
16 July	Nitrogen, 80 pounds	64.81	20.06	13.04
16 July	Phosphorus, 40 pounds	67.11	17.11	13.05
16 July	Potassium, 150 pounds	64.97	15.43	17.43
16 July	None	68.55	14.34	14.83
27 July	Nitrogen, 80 pounds	60.00	17.00	19.85
27 July	Phosphorus, 40 pounds	58.00	15.10	25.00
27 July	Potassium, 150 pounds	56.20	13.85	28.00
27 July	None	59.40	14.90	24.65
9 Aug.	Nitrogen, 80 pounds	66.75	....	32.35
9 Aug.	Phosphorus, 40 pounds	62.35	....	36.25
9 Aug.	Potassium, 150 pounds	59.50	....	39.35
9 Aug.	None	58.75	....	39.95
20 July	Nitrogen, 40 pounds	64.00	13.00	17.00
20 July	Phosphorus, 20 pounds	64.50	15.60	18.50
20 July	Potassium, 100 pounds	62.75	15.50	20.35
20 July	None	63.50	18.50	16.75
30 July	Nitrogen, 40 pounds	66.50	6.75	26.25
30 July	Phosphorus, 20 pounds	63.10	6.00	29.75
30 July	Potassium, 100 pounds	63.25	5.35	30.90
30 July	None	63.55	5.55	29.75
9 Aug.	Nitrogen, 40 pounds	66.25	....	32.35
9 Aug.	Phosphorus, 20 pounds	63.10	....	35.95
9 Aug.	Potassium, 100 pounds	63.10	....	35.70
9 Aug.	None	62.25	....	37.00

There is one exception to the statement that the nitrate plots yielded plants with heavier stems and leaves than the others, but this set of samples was taken quite early in the season, 16 July. It may be well to state, for the benefit of those who may compare the data given here with that given for 1913, that the plants at this time, 16 July, 1915, were several days (6 to 8) behind the plants on the same plots in 1913 in their development. It will be noticed that the weight of the heads, even up to 9 August, was as a rule less than from the other plots. This is entirely consonant with the results

of the season as shown by the weight of the threshed grain. How much of this result is to be attributed to the effect of rust and how much to that of the nitrate itself, is not clear, besides, these two questions cannot be judged separately, for it was evident that the nitrate plots suffered more from rust than the other plots. This fact we attributed to the effect of the nitrate upon the condition of the plant, not simply because it was lodged, but also because the nitrate had rendered it a better plant for the rust to grow on. One effect of nitrate has been stated in a previous bulletin to be the bringing about of an abnormal ripening, even when the weather conditions are favorable to a normal-ripening of the crop, and the quantity of nitrate is not sufficient to cause lodging.

THE DRY MATTER IN THE PLANTS OF 1915 CROP

The inference from the preceding discussion would be that the plants grown with nitrate were heavy in stems and leaves because they were bigger and not because they contained more water. This latter, however, was the case. The samples for 1913 showed this to be the case in every set of samples in comparison with plants grown with the application of phosphorus and potassium, which were either essentially equal to or less than those grown on the check plots. This excess of water tends to make the dry weight of the plants more nearly equal. The following table shows that the rule is that the plants grown on the plots which received potassium or phosphorus are the richest in dry matter, irrespective of variety, though the plants grown on the check plots are almost as rich, sometimes even richer in dry matter than those grown with phosphorus or potassium. The plants grown with the application of nitrates are, almost without exception, the poorest in dry matter, irrespective of the variety or the amount of nitrate applied. These observations are applicable to the samples of both seasons, 1913 and 1915, but the samples of the two seasons cannot be compared date by date, for the development of the plants in 1915 was retarded from 6 to 14 days, owing, I take it, to the weather conditions. This difference in the development of the plant increased with the season and the maximum difference was at the time of ripening. The ripening period was greatly influenced by the appearance of rust, which practically killed some of the Defiance.

DRY MATTER IN PLANTS GROWN WITH DIFFERENT FERTILIZERS—SEASON 1915

Date	Section	Fertilizer	Defiance	Red Fife	Kubanka
13 July	1700	Nitrogen, 120 pounds	21.30	25.25	25.00
13 July	1700	Phosphorus, 60 pounds	25.99	29.49	29.90
13 July	1700	Potassium, 200 pounds	25.20	30.87	30.59
13 July	1700	None	24.63	28.12	27.34
14 July	1800	Nitrogen, 80 pounds	19.75	25.15	26.29
14 July	1800	Phosphorus, 40 pounds	20.04	28.33	30.00
14 July	1800	Potassium, 150 pounds	25.46	30.31	31.87
14 July	1800	None	23.16	27.65	32.03
15 July	1900	Nitrogen, 40 pounds	28.63	30.62	29.53
15 July	1900	Phosphorus, 20 pounds	28.59	30.93	33.59
15 July	1900	Potassium, 100 pounds	29.63	32.97	33.59
15 July	1900	None	29.33	31.40	31.56
21 July	1700	Nitrogen, 120 pounds	25.31	27.50	33.28
21 July	1700	Phosphorus, 60 pounds	31.87	36.72	36.25
21 July	1700	Potassium, 200 pounds	31.25	35.62	36.25
21 July	1700	None	29.53	36.87	36.87
24 July	1800	Nitrogen, 80 pounds	28.43	33.75	33.90
24 July	1800	Phosphorus, 40 pounds	36.40	40.62	40.62
24 July	1800	Potassium, 150 pounds	35.62	38.90	38.75
24 July	1800	None	33.90	39.69	41.25
26 July	1900	Nitrogen, 40 pounds	35.46	37.65	38.94
26 July	1900	Phosphorus, 20 pounds	37.57	39.37	39.76
26 July	1900	Potassium, 100 pounds	37.50	40.00	40.47
26 July	1900	None	36.56	39.22	40.15
4 Aug.	1700	Nitrogen, 120 pounds	36.82	40.47	37.97
4 Aug.	1700	Phosphorus, 60 pounds	43.90	46.72	45.00
4 Aug.	1700	Potassium, 200 pounds	43.43	45.78	44.37
4 Aug.	1700	None	39.84	45.47	43.75
5 Aug.	1800	Nitrogen, 80 pounds	35.31	41.72	43.90
5 Aug.	1800	Phosphorus, 40 pounds	42.50	45.00	46.09
5 Aug.	1800	Potassium, 150 pounds	41.40	46.25	44.53
5 Aug.	1800	None	40.93	45.47	47.19
10 Aug.	1900	Nitrogen, 40 pounds	44.84	49.07	51.25
10 Aug.	1900	Phosphorus, 20 pounds	48.12	52.65	51.25
10 Aug.	1900	Potassium, 100 pounds	49.84	53.90	50.78
10 Aug.	1900	None	47.65	52.65	48.75

The dry matter given in the preceding table is the weight of the air-dried plants. In 1913 we found the air-dried material to contain from 5.566 to 8.652 percent of moisture; in 1915 we find the amount of moisture, in the few samples on which this determination has been made, much more uniform from 5.00 to 5.68 percent. It is but fair to state that all of the determinations made were on samples of Red Fife and may not hold strictly for the other varieties. The results, however, indicate that we are justified in assuming that the term air-dried means that the plants still contain an average of

not more than 7.5 percent of moisture, which is the average found for 1913.

The series of samples taken in 1915 is much larger than that taken in 1913, but the samples representing the same period of development yield quite closely agreeing results, which indicates that the influence of the weather upon this factor was much less than one would expect and further, that these conditions in no way eliminated or greatly modify the influence of the individual fertilizers.

Apropos of the influence of the date upon the development of the plant it may be added that the individual fertilizers are not wholly without effect upon this. It was a noticeable feature of the fields at one period in 1914 and again in 1915 that the wheat on the plots to which potassium had been applied was taller and appeared to be more advanced than that in the other plots, but this difference was entirely obliterated in a few days and afterwards no difference between these and the other plots could be observed.

THE EFFECT OF FERTILIZERS UPON THE NITROGEN CONTENT OF THE PLANTS

We do not wish to change any of the statements made in Part I (Bulletin 208), p. 35, in regard to the reasons for presenting this subject, the scope of the work, or the variety chosen. All that we then said applies to our work still.

We will add, however, the subject of the nitric nitrogen in the plant. This subject was passed over in Part I (Bulletin 208) because we wished to repeat our observations and extend our analytical work, which we have been able to do during the present season, and the results will be given in their proper place.

TOTAL AND PROTEID NITROGEN IN GROWING WHEAT PLANTS, 1915

Date	Fertilizer	Stems	Total			Proteid		
			Leaves	Heads		Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	.2797	.8092	.6324		.1598	.5838	.4066
13 July	Phosphorus, 60 pounds . . .	.2050	.6150	.5629		.1270	.3946	.3614
13 July	Potassium, 200 pounds . . .	.2050	.5907	.5803		.1286	.4170	.3683
13 July	None	.1911	.5837	.5456		.1216	.3981	.3545
16 July	Nitrogen, 80 pounds	.2777	.6463	.6376		.1843	.5018	.4239
16 July	Phosphorus, 40 pounds . . .	.2084	.4639	.5872		.1529	.3892	.4045
16 July	Potassium, 150 pounds . . .	.2359	.4934	.6185		.1494	.3753	.4149
16 July	None	.2102	.5786	.5959		.1490	.4309	.3593
20 July	Nitrogen, 40 pounds	.2613	.4361	.5803		.1891	.3662	.4274
20 July	Phosphorus, 20 pounds . . .	.2376	.4100	.5699		.1703	.3475	.3906
20 July	Potassium, 100 pounds . . .	.1963	.3179	.5542		.1425	.2828	.3788
20 July	None	.2120	.3509	.5629		.1430	.2884	.3732
23 July	Nitrogen, 120 pounds	.3457	1.2561	.7644		.2220	.1077	.5386
23 July	Phosphorus, 60 pounds . . .	.2357	.6915	.6376		.1668	.0312	.4392
23 July	Potassium, 200 pounds . . .	.1998	.6880	.5924		.1390	.0660	.4378
23 July	None	.2324	.6915	.6116		.1613	.5052*	.4309
27 July	Nitrogen, 80 pounds	.2884	.4621	.6533		.1824	.3461	.6533
27 July	Phosphorus, 40 pounds . . .	.1964	.2187	.5212		.1432	.1703	.5212
27 July	Potassium, 150 pounds . . .	.2187	.2988	.5872		.1613	.2168	.5838
27 July	None	.1928	.2797	.5247		.1390	.2234	.5247
30 July	Nitrogen, 40 pounds	.2654	1.0260	.7297		.1842	.5699	.5734
30 July	Phosphorus, 20 pounds . . .	.2204	.7679	.6585		.1703	.6116	.4934
30 July	Potassium, 100 pounds . . .	.2015	.5942	.6550		.1369	.1890	.5365
30 July	None	.2102	.7401	.6324		.1543	.2954	.4830
6 Aug.	Nitrogen, 120 pounds		.4169	.9221		.2967		.7794
6 Aug.	Phosphorus, 60 pounds . . .		.2289	.6759		.1598		Lost
6 Aug.	Potassium, 200 pounds . . .		.2154	.7210		.1369		.5817
6 Aug.	None		.2671	.6533		.1855		Lost
9 Aug.	Nitrogen, 80 pounds		.4500	.9069		.2898		.7401
9 Aug.	Phosphorus, 40 pounds . . .		.2498	.6741		.1876		.5595
9 Aug.	Potassium, 150 pounds . . .		.2726	.7747		.2030		.6568
9 Aug.	None		.2550	.7019		.1890		.5699
12 Aug.	Nitrogen, 40 pounds		.3787	.8895		.2780		.8023
12 Aug.	Phosphorus, 20 pounds . . .		.3110	.7158		.2255		.6950
12 Aug.	Potassium, 100 pounds . . .		.2272	.8286		.1703		.7815
12 Aug.	None		.2726	.8040		.2050		.6915

* This result appears abnormal. The whole set was repeated with the same results.

The table, when compared with a similar statement obtained for the crop of 1913, indicates that the amounts of total and proteid nitrogen are smaller throughout the season of 1915 than in 1913; the same conclusion is indicated for the dry matter, but when one considers plants of the same development we find that the difference in dry matter is not very pronounced, while the percentage of nitrogen is decidedly lower and holds, in the main, for the whole season. In both seasons we see that the application of nitrogen increased these forms of nitrogen in the plant, and these differences

are quite as pronounced in 1915 as in 1913, showing that, while the season influenced the whole problem, it did not obscure the effects of the nitrate. The most noted differences are shown by the samples of the heads as they approached ripeness. The total nitrogen in the heads of the last four samples, gathered 5 August, 1913, averaged 1.2587 percent, but in those on 9 August, 1915, from the same plot of ground and of the same variety of wheat, the average was only 0.7644 percent. A difference is shown by the earliest samples gathered in the respective years, but the difference is smaller, 0.1675 against 0.4943 percent. The differences between the total nitrogen in the heads of the plants for the respective years increased as the plants matured. This was probably not due to the total supply of nitrogen in the soil, for, if we compare the plants grown with the application of 120 pounds of nitrogen per acre, in the form of sodic nitrate, at the time of full bloom, we find that the heads in 1913 contained 0.7607 percent of nitrogen; in 1915, the same variety, grown on the same land, and also with the application of 120 pounds of nitrogen, contained 0.6324, showing a difference of 0.1283 percent, which is a little less than the average found for all of the plots in this section, i. e., 0.1675. This difference increased during the season. These results, especially those obtained with mature plants, all involve the question of the effects produced by the abundant appearance of rust.

I have no way of estimating how great the influence of this factor was, nor of conveying any definite idea of the severity of the attack, but it was very bad, even on Red Fife, the variety used for the nitrogen work, while it ruined the Defiance. The factors appearing in this year's work are the fertilizers applied, the weather conditions, and the effects of the rust. The same factors were operative in 1913 also, but they were very different, the rainfall, for instance, in 1913, between 18 May and 7 July, the date on which the first samples of plants were taken, was 0.36 inch, in 1915, for the same period, 18 May till 13 July, the date of taking the first sample, it was 5.94 inches. In the former year we applied, on 12 June, one foot of water, in the latter 0.6 of a foot, also on 12 June, so that the amount of water received by the plots was essentially the same, but, in 1913 the water was applied to the land in practically one application, while the plants, throughout the period considered, were scarcely wet at all and the weather was clear. The quantity of water received in 1915 was smaller by less than one inch, but its application and distribution were different, the plants themselves being kept almost continuously wet by frequent light rains, and cloudiness prevented their rapid drying. The mean temperature, too, was a little lower in 1915 than in 1913. As the differences existed early in the season, before the appearance of the rust, we cannot

consider the latter as the cause of it at that time. All that we can say is that the rust intensified this effect and apparently produced a similar if not an identical result. If we compare the ratio of the total nitrogen to the proteid nitrogen in the heads for the last eight samples taken in 1913, and for the last ten samples taken in 1915, we find it higher in 1913 than in 1915, 1.18 against 1.03; that is, the total and proteid nitrogen in the heads at the end of the season were more nearly equal in 1915 than in 1913, though both were decidedly lower in 1915. There was not only less protein in the whole plant than in 1913, but a larger percentage of it remained in the leaves and stems (straw).

AMMONIC AND AMID NITROGEN IN WHEAT PLANTS IN 1915

Date	Fertilizer per Acre	Ammonic Nitrogen			Amid Nitrogen		
		Stems	Leaves	Heads	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	.00265	.00638	.00638	.00597	.00270	.00665
13 July	Phosphorus, 60 pounds . . .	.00529	.00162	.00652	.00299	.00358	.00802
13 July	Potassium, 200 pounds . . .	.00162	.00475	.00692	.00270	.00489	.00162
13 July	None	.00189	.00393	.00610	.00243	.00407	.00816
16 July	Nitrogen, 80 pounds	.00299	.00707	.01768	.01224	.00625	.01034
16 July	Phosphorus, 40 pounds . . .	.00216	.00434	.00789	.00380	.00380	Lost
16 July	Potassium, 150 pounds . . .	.00216	.00652	.01088	.00366	.00434	.01224
16 July	None	.00216	.00734	.00925	.00270	.00489	.01101
20 July	Nitrogen, 40 pounds	.00216	.00339	.00789	.00270	.00299	.00979
20 July	Phosphorus, 20 pounds . . .	.00243	.00366	.00879	.00284	.00420	.00965
20 July	Potassium, 150 pounds . . .	.00189	.00366	.00897	.00270	.00256	.00665
20 July	None	.00216	.00353	.00843	.00216	.00284	.01101
23 July	Nitrogen, 120 pounds	.00610	.00992	.01468	.00556	.01170	.01427
23 July	Phosphorus, 60 pounds . . .	.00189	.00610	.00816	.00299	.00570	.00652
23 July	Potassium, 200 pounds . . .	.00189	.00652	.00610	.00216	.00434	.00393
23 July	None	.00216	.00516	.00816	.00216	.00489	.00679
27 July	Nitrogen, 80 pounds	.00189	.00763	.00817	.00353	.00583	.00592
27 July	Phosphorus, 40 pounds . . .	.00162	.00326	.00707	.00202	.00284	.00434
27 July	Potassium, 150 pounds . . .	.00189	.00353	.00925	.00353	.00216	.00457
27 July	None	.00162	.00339	.00843	.00175	.00216	.00652
30 July	Nitrogen, 40 pounds	.00202	.01183	.00707	.00339	.01387	.00870
30 July	Phosphorus, 20 pounds . . .	.00162	.00570	.00843	.00216	.00707	.00610
30 July	Potassium, 100 pounds . . .	.00162	.00366	.00789	Lost	.00543	.00447
30 July	None	.00148	.00420	.00856	Lost	Lost	Lost
6 Aug.	Nitrogen, 120 pounds	.00679		.00665	.00843		.00707
6 Aug.	Phosphorus, 60 pounds . . .	.00284		.00679	Lost		.00380
6 Aug.	Potassium, 200 pounds . . .	.00353		.00462	.00420		.00407
6 Aug.	None	.00284		.00638	None		.00162
9 Aug.	Nitrogen, 80 pounds	.00734		.00353	.00816		.00747
9 Aug.	Phosphorus, 40 pounds . . .	.00270		.00543	.00407		.00515
9 Aug.	Potassium, 150 pounds . . .	.00407		.00353	.00570		.00489
9 Aug.	None	.00261		.00652	.00366		.00720
12 Aug.	Nitrogen, 40 pounds	.00762		.00734	.00638		.00543
12 Aug.	Phosphorus, 20 pounds . . .	.00489		.00462	.00434		.00502
12 Aug.	Potassium, 100 pounds . . .	.00543		.00462	.00407		.00353
12 Aug.	None	.00434		.00407	.00489		.00665

NITRIC NITROGEN IN GREEN AND DRY WHEAT PLANTS 1915

Date	Fertilizer per Acre	Green Plants			Dry plants, but Calculated Back to Green Plants		
		Stems	Leaves	Heads	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	.02269	.01341	None			
13 July	Phosphorus, 60 pounds . . .	Trace	None	None			
13 July	Potassium, 200 pounds . . .	.00054	None	None	No samples preserved		
13 July	None	None	None	None			
16 July	Nitrogen, 80 pounds	.01996	.01179	None			
16 July	Phosphorus, 40 pounds . . .	None	None	None			
16 July	Potassium, 150 pounds . . .	.00039	None	None			
16 July	None	Trace	None	None			
20 July	Nitrogen, 40 pounds	.00620	.00069	None	.02163	.00514	None
20 July	Phosphorus, 20 pounds . . .	.00043	None	None	.00087	None	None
20 July	Potassium, 100 pounds . . .	.00024	None	None	None	None	None
20 July	None	None	None	None	None	None	None
23 July	Nitrogen, 120 pounds	.02886	.01226	.00048	.01995	.01954	.00014
23 July	Phosphorus, 60 pounds . . .	None	None	None	.00028	None	None
23 July	Potassium, 200 pounds . . .	None	None	None	.00024	None	None
23 July	None	None	None	.00034	None	None	None
27 July	Nitrogen, 80 pounds	.03283	.00296	None	.00690	.00061	None
27 July	Phosphorus, 40 pounds . . .	.00126	.00034	None	None	None	None
27 July	Potassium, 150 pounds . . .	.00043	None	None	None	None	None
27 July	None	None	None	None	.00030	None	None
30 July	Nitrogen, 40 pounds	.00489	.00134	None	.00551		None
30 July	Phosphorus, 20 pounds . . .	.00059		None	None		None
30 July	Potassium, 100 pounds . . .	.00093		None	.00050		None
30 July	None	Lost		None	None		None
6 Aug.	Nitrogen, 120 pounds	.02986		None	.03498		.00038
6 Aug.	Phosphorus, 60 pounds . . .	None		None	None		None
6 Aug.	Potassium, 200 pounds . . .	Trace		None	.00018		None
6 Aug.	None	None		None	Trace		None
9 Aug.	Nitrogen, 80 pounds	.02961		Trace	None		None
9 Aug.	Phosphorus, 40 pounds . . .	None		None	None		None
9 Aug.	Potassium, 150 pounds . . .	None		None	None		None
9 Aug.	None	None		None	.00018		None
12 Aug.	Nitrogen, 40 pounds	.00451		None	None		None
12 Aug.	Phosphorus, 20 pounds . . .	.00046		None	None		None
12 Aug.	Potassium, 100 pounds . . .	None		None	None		None
12 Aug.	None	.00023		None	Trace		None

These tables, taken together with the one giving the ammoniac and proteid nitrogen, present some instructive features. Assuming that the nitrogen used by the plants is furnished wholly by the soil in the form of nitrates, which in our case is probably true, and referring to the tables giving the nitric nitrogen for the respective years, we see that we have no reason to believe that there was a less supply in 1915 than in 1913. The table entitled "Distribution of the Ni-

trates in the First Foot and the Succeeding Three Feet of Soil in 1913 and 1915'' shows plainly that the total amount in the top four feet of soil was not less in 1915 than in 1913, but it also shows that the distribution was quite different in the two years. This, however, should make but little difference, for reference to the tables giving the nitric nitrogen in the soil samples taken throughout the season to a depth of four feet, show that the fourth foot does not usually, even in 1915, when our soil was kept moist by a succession of moderate rains, contain any large quantity of nitric nitrogen. We consider this depth the limit of the feeding area of the wheat plant. But if this should be too great a depth to take under our conditions, and if the plants do not feed to a greater depth than three feet, this would not alter the statement made relative to the total supply of nitric nitrogen in the two years. Further, any question concerning the relative supply of nitric nitrogen which might apply to the check plots in the respective years, could scarcely apply to the plots to which we applied 120 pounds of nitric nitrogen per acre in three applications, made at intervals of approximately four weeks, with the purpose of maintaining an excessive supply of this form of nitrogen in the soil. The first application of 40 pounds of nitrogen per acre was harrowed in to a depth of from two to three inches. We had to depend upon the rain and irrigating water for the distribution of the succeeding applications. We made no attempt to follow the distribution of these 120 pounds of nitrogen through the soil. It might have been interesting if we had been able to do so and further to have determined what portion of it was utilized by the plant and how much of it was lost in the soil. We have, in our observations of the effects produced upon the plants, a basis for a very rough estimate of the relative effects of the quantities, 40, 80 and 120 pounds, applied to the different plots. This rough judgment is that 80 pounds, applied in two portions of 40 pounds each, produces on our soil, almost, if not altogether, as great effects as 120 pounds applied in three portions of 40 pounds each. The effects of 40 pounds, applied at the time of planting, produce quite as deep a color in the growing plants, and the limits of the area to which it has been applied are quite as definitely marked as those of 80 or 120 pounds. This statement does not hold in other respects, for we shall see that the effects of the larger applications are quite regularly bigger than those of the smaller applications. It does not seem probable that either the quantity of nitric nitrogen present in the two years, or the distribution of the same in the soil, varied enough to produce the differences in the nitrogen content of the plants which we actually find. The stems constitute approximately 65 percent of the total plant, and while the amount of nitrogen present is smaller than

in the leaves, and the part played by the latter in the economy of the plant may be greater than that of the stem, still the general effects of the fertilizers and of the seasons may be quite clearly seen in this portion of the plant, so we will consider the stems only, whereby we sacrifice nothing of the truth and gain much in brevity.

In the samples of the stems taken in 1913 we see that the total nitrogen is increased by the application of nitrates, and while this increase is not proportional to the amounts applied to the different sections of land, it is true that up to the end of July the stems of those plants grown with the largest application of nitrates contain the highest percentage of nitrogen. This relation was no longer evident when the plants have become so nearly ripe that it was no longer possible to separate the stems and leaves. It has elsewhere been stated that the sheaths are, for the most part, taken with the stems.

The amount of total nitrogen in the stems during the season of 1915 is much smaller than in 1913, but those grown with the application of nitrates are uniformly higher than those grown without it. The total nitrogen in the stems in 1915 is roughly equal to three-fourths of that present in 1913. This is true of the nitrogen in the stems up to the end of July only; from this time till harvest the stems, with whatever leaves were left, in 1915, contain more nitrogen than they did in 1913, while the heads contained very much less nitrogen than in 1913. In other words, the nitrogen was not transferred from the stems and leaves to the heads in 1915 to the same extent that it was in 1913. The ripening period did not produce the changes taking place during this period in the same thorough manner in the former as in the latter season.

These facts divide our considerations in two parts. The first part brings us to the beginning of the ripening period, and the second consists of this period. This is a natural and common division, which we observed in writing Part I (Bulletin 208), but for entirely different reasons than now.

The facts that we have presented show that the effects of the nitric nitrogen applied to the plots are of the same character and persistent throughout the two very dissimilar seasons. The same is true of the phosphorus and potassium, but in so far as the nitrogen content of the plant may be relied upon as an indication, the composition of the plants were quite unlike, all parts examined, stems, leaves and heads, were richer in total and proteid nitrogen in 1913 than in 1915, without regard to the amount of this element in the form of nitric nitrogen at the disposal of the plant.

The effects of phosphorus and potassium are, as in 1913, so indefinite and irregular that the small variations observed are not en-

titled to consideration. The plants from the three check plots show quite as great variations among themselves as we find between these and the phosphorus and potassium plots. It must be remembered, however, that there is no compelling reason why plants grown on three abutting check plots should be identical in composition, especially if our contention that differences in the supply of plant food produces differences in the composition of the plant, and we may anticipate a little by adding, if its seeds, too, be correct. We have shown by experiment what we all know, that soil varies in the amount of total and of nitric nitrogen from foot to foot. (See Part I (Bulletin 208) p. 26.) We have further given, in former publications on the subject of Fixation of Nitrogen In Our Colorado Soils, instances of very great variations of nitrates within a few feet, variations of hundreds or even thousands of parts per million. Identity of results cannot be expected, but larger and persistent differences, such as we find occurring in all of the series of plants presented in Part I, and in this one, are founded on something more than accident; they have some general and sufficient cause.

Further, while the effect of the nitric nitrogen is evident and persistent through the two seasons, the total nitrogen in the plants in 1915 is only about three-fourths of that present in 1913. In this statement we compare 32 samples in 1913 with 36 samples taken in 1915. As stated, the relative effects of the respective fertilizers are discernable throughout both series. The seasons were dissimilar and this difference would appear to be the direct cause of the differences in the nitrogen content up to the end of July, or during the vegetative period. The factor which caused this difference can not be the total amount of water supplied by way of the soil, for that applied by irrigation and rainfall during the two seasons was very nearly the same. This is on the assumption that all the rainfall reached the ground, which is not correct. But if the amount of water supplied by the soil had been different, other results would still compel us to eliminate this as the cause for the difference. It is fortunately the fact that some of our plots in 1913 received during the season 30 inches of water, whereas, in 1915, the total received was a little over 19 inches. The samples from these plots receiving 30 inches of water in 1913 contained as much nitrogen as the corresponding plots that received 19 inches, so that a difference of 11 inches of water applied to the soil made no difference in the amount of total nitrogen contained in the stems, which we have used as representative of the whole plant. The same is true of the proteid nitrogen, or, perhaps I should say, that the differences are so small and irregular that we cannot consider them in this work.

These facts are in harmony with others obtained with the wheat berry grown with different quantities of water.

We are justified by the latter facts in going further and asserting that the time of the application of water to the soil, provided there be at all times a sufficient amount of water present, does not make the differences which we are considering. This statement contemplates the application of water to the soil up to within fifteen days of the harvest. These statements are, however, in anticipation of the discussion of the work done with the berry and not with the plant.

There are three facts left in the problem, the prevailing temperature, the application of the water to the plant, not to the soil, and the sunshine. While it may be true that the temperature affected our problem, it seems difficult to believe that a difference of a few degrees should make such a radical difference in the amount of the total nitrogen in the plant, especially as the mean temperature for July was 64.74 and for August 62.77, which includes a period from before blooming till the maturity of the plant.

I am not conversant with any data on the minimum energy requirements of the wheat plant that serves to aid me in a solution of this question, but until I obtain further light upon the question, I shall consider the heat energy at the disposal of the plant as fully adequate. If this view be correct, we have left but two factors, the application of the water to the plants in frequent light rains and the prevalent cloudiness of the season. The determining factor seems to be either a combination of these two, or one or the other of them. It is a fact that the plants were wet a great deal of the time either from rain or dew. I do not think that we, at any time during the season, collected a sample of dry plants, except near or after midday, and the plants were often wet throughout the day. This fact impresses itself upon me as of great importance in our problem. Had we had wet plants, as we did have, and at the same time our usual amount of sunshine, I imagine that things would have stood much worse with us than they did at the end of July, for the plants would certainly have been scalded, if no worse trouble had ensued.

I do not intend in any way to indicate that continued cloudiness is not a factor in this question, but at the present time I believe that the frequent light rains and consequent heavy dews which kept our plants dripping wet for so large a portion of each day, often all day long, was the more important factor of the two. I do not recall having seen any data on this point and have made no experiments myself to study the effects of such conditions.

We have said nothing about the ripening period. The principal reason for this is, that in 1913 the transference of the nitrogen from the plant to the seed, or its elimination from the plant, went on till the total in the plant was reduced far below what it was during the vegetative period; this was not the case in 1915. The total nitrogen in the plant remained high and the amount in the head did not increase as it did in 1913. In 1913 the season was very favorable, in 1915 it was quite unfavorable for the maturing of a good crop. One result of the unfavorable crop season of 1915 was the development of rust on all three varieties of wheat grown, but it injured the Red Fife, whose composition we have given for two years, 1913 and 1915, perhaps the least of the three. The indications are that the normal processes in the wheat during the ripening period were seriously interfered with, and while the changes may have been normal in their general character, which admits of a doubt, they were at least incomplete. The severe attack of rust was a direct result of the weather conditions. It was fortunate for us that we had chosen the Red Fife for our study. Had we chosen Defiance we would have been unable to obtain any results that we would have felt willing to use, because the crop was ruined, especially on those plots to which sodic nitrate had been applied. That these plots were more susceptible than the others to attack by this fungus can scarcely admit of a doubt. We might express the reasons otherwise. The plants were large, succulent, badly lodged, almost continuously wet, and rusted. The other plots were very severely attacked, but they were not so severely, and the wheat yielded was better than that of the nitrate plots, though very far from good. The Red Fife is naturally several days earlier and probably more resistant to the effects of rust than the Defiance. It is from such considerations that we conclude that the course of the changes in the plant, including also the heads during the ripening period of 1915, was greatly interfered with by this fungus, and that this is the cause of the results obtained. The weather conditions, especially those features which kept the plants continuously wet, were accountable for the low nitrogen in the plants up to the end of July. But during the ripening period the immediate cause of abnormal development was the severely diseased condition of the plants, and the effects of the weather conditions proper are concealed by the effects of the rust.

The ammoniac, amid and nitric nitrogen in the plants are considered of less importance in this question than the total and proteid nitrogen. The presence of nitric nitrogen in the wheat plant is probably altogether dependent upon an accidental excessive supply in the soil, while the ammoniac and amid nitrogen are intermediate and transient forms in the plant. The proteid nitrogen, on the other

hand, is presumably the end product of the transformations and while it may be transferred from one part of the plant to another by little-understood processes, it represents the most permanent form of nitrogen in the plant. It is, however, evident that the total nitrogen includes a very considerable amount of nitrogen in other forms; at the end of July only about 60 percent of the total nitrogen is present as proteid nitrogen, nitrogen precipitated by Stutzer's reagent, and at the end of the ripening period in a few cases as much as 70 percent. The latter figure was obtained in 1915, when both the total and proteid nitrogen in the plant were very high compared with the results obtained in 1913.

I have stated that the nitric nitrogen appearing in the wheat plant owes its presence to an excessive supply of this form of nitrogen in the soil, and is probably accidental. This statement is based upon the fact observed in all of the samples examined during the two years, i. e., that the plants grown with the application of sodic nitrate regularly contain some nitrogen in this form, while those grown without it contain either only a very small amount, or no nitric nitrogen at all. The table contains only the results of 1915 and none of those of 1913. At one time we thought that oxidation in the air-dried plant actually took place, but were unable to establish this, and now believe that any nitric nitrogen found, even in the dried plant, represents an unused excess originally derived from the soil. The method used in determining the nitric nitrogen in the plant may give us slightly low results, but it certainly does not give us high results, so I think that we can depend upon our results as corresponding to the facts, especially as we took 150 grams of the green plant, or an equivalent amount of the dried plant, for the determinations. We found no nitric nitrogen in the heads. The facts are, in the main, concordant with what is known regarding the occurrence of nitrates in wheat plants. Jost, in his *Plant Physiology*, p. 140, says "Tobacco, turnips, sunflowers, potatoes and wheat may be taken as examples of cultivated plants which contain large quantities of nitrates. In the last two the nitrate amounts to from 1.5 to 2.8 percent of the dry weight. * * * The maximum of nitrate is found in the root, less in the stem and leaf, none at all in the seed. The nitrate increases as the flowering period approaches and decreases when fruiting takes place. * * Such storing of nitrate, however, is by no means universal. Many plants absorb no more than they absolutely require." It will be noticed that the amounts that we have found in our samples, grown with the application of 120 pounds of nitric nitrogen per acre, are far below the quantity given by Jost. In summarizing the lecture from which the above quotation is taken, Jost says we have learned "that nitric acid is the chief source of nitrogen, and that that element in co-operation with carbohydrates goes to form proteid especially." (p. 145). To quote Jost again, *Plant Physiology*, p. 174: "Schultze assumed that the amino-acids first arising from the proteid substances, in addition to which perhaps

also primarily asparagin and glutamin may arise, break down further into ammonia and form this, in presence of suitable carbohydrates—perhaps glucose—asparagin and glutamin are constructed. These amids would be thus, not the main products of decomposition, but rather the first stages in a higher synthesis and their formation from this point of view is not inconceivable. According to Hausteen's experiments the amino-acids appear—so far as they have been investigated—much less adapted to the formation of proteids than ammonia and the two amids above mentioned. * * * * This hypothesis of Schultze's which has been recently supported by Balicka-Iwanoska (1903), (and also by Prianischnikow, 1904 and earlier), appears to us to explain best the facts known to us at the present time in this difficult region of investigation. * * * *

'A new difficulty presents itself when we attempt to investigate how proteids arise from amino-acids and amids. It cannot be doubted that the process takes place in light and Pfeffer (1873) has further given proof that light acts indirectly in the process.'

The nitrogenous material out of which the proteids are built is primarily nitric acid, the principal intermediate products are ammonia and the amids, and these may occur in our wheat samples in varying quantities according as their transformation into proteid is more or less complete. We observe that corresponding to this theory we find the nitric, ammoniac, amid, proteid and also the total nitrogen highest in those samples grown with the application of nitrates, which we used in liberal quantities for the purpose of discovering if possible the specific effects of nitric nitrogen, especially upon the character of the kernels produced.

THE ASH CONSTITUENTS OF THE PLANTS

We have not repeated the work of 1913 on this subject except to determine the ash constituents in one set of samples of the whole plant taken 5 August, 1915. We gave one set of samples for Fife in Part I, taken 31 July. The plants at this date in 1913 were as mature, or perhaps rather more so, than plants of the same variety on 5 August, 1915. The results obtained with the 1913 samples present the effects of the fertilizers upon the ash constituents under favorable seasonal conditions. The results of 1915 will serve to show the same thing under unfavorable seasonal conditions, and in these particular cases also the character and extent of the changes that we may attribute to the weather conditions.

ASH CONSTITUENTS OF WHEAT PLANTS—CROP 1915

Red Fife	Ca.	Mg.	Fe.	Mn.	K.	Na.	P.	S.
Fertilizer per Acre	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.
Nitrogen, 80 pounds	0.156	0.107	0.022	0.004	1.376	0.026	0.084	1.469
Phosphorus, 40 pounds	.116	.094	.007	.004	.868	.035	.058	1.527
Potassium, 150 pounds	.087	.0106	.012	.004	.980	.031	.061	1.627
None	.105	.073	.014	.004	.972	.041	.091	1.828

The sulphur and chlorine were not determined. These determinations were omitted also in the 1913 series.

The above series, though consisting of fewer members than might be desirable, shows the same effects upon the relative amounts of the ash constituents as in 1913, when we analyzed 12 instead of 4 samples of straw as in 1915. The specific effects of the nitrate were to increase the calcium, potassium and magnesium and to depress the silicon; we see the same features in the above results. In 1913 it produced no appreciable effect upon the amount of phosphorus. The check plot was of course adopted as our standard. In the results of 1913, we observed that the application of phosphorus and also that of potassium tended to depress the phosphorus in the plant. We observe the same tendency in 1915. While the nitrate depressed the silicon, it increased the potassium, calcium and, in a less degree, the magnesium. The net result, however, was to increase the ash. The increase in 1915 is very slight, so slight that one can scarcely claim it to be satisfactorily decisive. If we compare the amount of these constituents for the two years, we will find it from 0.340 to 1.0 percent lower in each of the four samples than in 1913. On looking at the individual constituents we observe that the potassium suffers approximately one-third of this depression, though all of the ash constituents participate in it.

The weather conditions have already been given in some detail. It has been stated that the plants were kept wet a great portion of the time. Whether this is the cause of the lower ash constituent or not, it is a fact and seems to me the probable cause.

In considering the nitrogen compounds in the plants we had two series of effects, one of which we attributed to the fertilizers and which was consistent throughout the two seasons. The other we attributed to the weather conditions. In addition to these two series of results, which seemed to run parallel up to the end of July, we had a third series of results which was not consistent at all for the series of samples taken after 30 July in the respective years. These results I believe to have been effected by the action of the rust. The results obtained by the study of the ash constituents of the plants in the two years are in harmony with those obtained by that of the nitrogen compounds up to the end of July, the latest date to which our work on the ash constituents can be applied.

SUMMARY

The summary includes the facts presented in Part I, with which no summary was presented, because we intended to record the results of another season's work on the subject dealt with before we formulated our conclusions.

We believe that the fundamental condition in this work is the question of food supplied by the soil; the weather conditions are important, but accidental.

The land used for these experiments contains a liberal supply of total potash. We found in 1913 that in the top two feet of soil there was 101.6 tons of this substance per acre, of which approximately one ton was available at that time. If, however, we base our estimate on the hydrochloric acid-soluble potash, we find that there was over 25 tons available. The citric acid, soluble phosphoric acid was about 1,400 pounds, that soluble in hydrochloric acid, 9,800. The total nitrogen found in the same depth of soil was 8,240 pounds. The amount of plant food was considered ample. This estimate, however, was based not entirely upon analytical results, but the crops produced by the land were also considered.

The nitrogen, while sufficient, was not considered remarkably high. It was shown that a very considerable portion of this nitrogen actually existed in the soil in the form of nitric nitrogen at the time of planting. The top two feet contained nitric nitrogen equivalent to 211 pounds of sodic nitrate. The biological conditions of the soil are such that the conversion of the soil nitrogen into nitric nitrogen proceeds rapidly.

The power of this soil to fix nitrogen has been discussed in previous publications (Headden, Bulletin 178, p. 89; Sackett, Bulletin 179, p. 29), in which it is shown that this factor is a very important one, being sufficient to add very considerable quantities of nitrogen to the soil annually, provided the conditions be reasonably favorable. I may emphasize this fact by giving the results of observations made on a sample of soil from this tract of land, but not from either of the three sections used for these wheat experiments. The sample was kept in a large bottle, loosely corked, at the temperature of the laboratory. There was no opportunity for the soil to absorb ammonia or nitric fumes. This sample was put into the bottle just as it was brought from the field, except that the clumps were broken up and the soil made reasonably fine. In 27 days this soil gained 4.82 milligrams of nitrogen for each 100 grams of soil, or 48 parts per million. This soil had nothing added to it, nor was it treated in any way to facilitate this bacterial activity, except that it was kept in a moderately warm room. This was the smallest gain observed by myself or Prof. Sackett in samples of this soil. The other samples, however, were incubated and the moisture was

brought up to about the optimum quantity. Even at this minimum rate of fixation, the amount of nitrogen added to the soil in one month would be sufficient, if nitrified, to nourish several crops of wheat. So it is by no means necessary that even this minimum observed rate of fixation should be maintained throughout the year in order that this process should form a factor demanding our consideration. This amount of fixation means the addition of 192.8 pounds of nitrogen to an acre-foot of soil in one month, equivalent to the addition of about 1,100 pounds of sodic nitrate. We have nowhere intimated that we hold this nitrogen to be available in this form, but have taken, tacitly it may be, the extreme view that only nitric nitrogen is available to the wheat plant.

It is because of the importance and immediate connection of this latter form of nitrogen, with the growth, yield and, as I believed when I began this work, with the character of the wheat produced, that we have given in some detail the moisture and nitric nitrogen in the soil throughout the two seasons of 1913 and 1915. The moisture is not only necessary to the growth of the wheat plant, but also to the biological factors in the soil. We determined the moisture in the soil for the latter reason quite as much as for the former, and endeavored to determine the effects of irrigation upon the distribution of the nitrates. In 1913, we found a very great difference in the amount of, and also in the distribution of, the nitrates on the different dates, 29 April, before irrigation, and on 27 June, thirteen days after irrigation. These differences were so big that the usual considerations of variability due to differences in samples from place to place within limited areas, are wholly excluded. In the top four feet of one sample we found on 29 April, nitric nitrogen equivalent to 1,908 pounds of sodic nitrate; in another on the same date, for the same depth of soil, the equivalent of 471 pounds; but in this latter sample we find in the 7th, 8th and 9th foot, taken together, the equivalent of 721 pounds. On 27 June, after irrigation, we found for the top four feet of three different sections of soil, 162, 91 and 156 pounds, respectively, and below the depth of four feet, usually from six to eight pounds per acre-foot; but this amount varies somewhat; the maximum found below four feet in three borings taken to a depth of 12 feet was 30 pounds to the acre-foot, the minimum was nil. In the cropped land the nitric nitrogen, especially during the actively vegetative period of the plants, usually falls to less than an equivalent of 20 pounds of sodic nitrate per acre-foot of soil, except in the top three or perhaps six inches, where it is usually a little higher, provided the sample be not taken immediately after a rain. The surface portions of land cropped to wheat may occasionally show nitric nitrogen equivalent to as much as 200 pounds of sodic nitrate to the acre-foot, but in most cases we found from 30 to 40 pounds in such samples. In 1913, the second

foot seldom showed as much nitric nitrogen as would be equivalent to 20 pounds of sodic nitrate per acre-foot. This was a season of high rainfall in general, and long periods without any. In 1915, with twice the total rainfall, which fell in a succession of light rains well distributed throughout the season, we have a very different distribution of the nitric nitrogen, for we find even the fourth foot containing, at the end of June, as high as the equivalent of 48 pounds of sodic nitrate; but by 3 August, the nitric nitrogen had been used up to such an extent, that the surface foot contained the equivalent of only about 20 pounds of sodic nitrate; the minimum found in the fourth foot at this time was nil. The nitric nitrogen had disappeared from all of the plots in the same manner and to about the same extent. The amount of nitric nitrogen in the top four feet of soil was at all times throughout the season larger in 1915 than in 1913. This fact was due, in all probability, to the different distribution of the moisture. The period of minimum nitrates in the soil was, in 1915, 3 August, or the beginning of the ripening of the grain. The effects of the crop upon the nitric nitrogen in the soil were checked by cutting out the wheat on a small section 20 by 20 feet, and keeping it fallow throughout the season. Samples were taken from this fallow ground, and also from that occupied by the wheat plants on 3 August, 1915, to a depth of four feet. The nitric nitrogen present in this fallow land to this depth was equivalent to 285.5 pounds of sodic nitrate; that present in the cropped land, to the same depth, was equivalent to 46.9 pounds of sodic nitrate. The crop, either by preventing the formation of the nitrates, or by using them up, had made a difference equal to 238.6 pounds of sodic nitrate in this depth of soil.

It was shown in Bulletin 178, p. 91, and again by Sackett in Bulletin 193, sample No. 75, pp. 24 and 39, that the nitrifying efficiency of this soil is relatively high. In Part I (Bulletin 208), pp. 20 and 21, I showed the differences in the amount of nitric nitrogen in land cultivated fallow during the season, and in that cropped to spring wheat, for samples taken on 4 December, 1914. I also gave the amount of nitric nitrogen found in the cropped land on 1 August, 1913. The average given by three sets of samples, each composed of eighteen sub-samples, taken to a depth of nineteen inches, corresponds to 542.43 pounds of sodic nitrate per acre for the fallowed land. The nitric nitrogen found in one of our check plots of Defiance wheat on 1 August, 1913, taken to a depth of two feet, corresponded to 101.20 pounds sodic nitrate per acre. This same plot was cropped to wheat in 1914, the wheat was harvested 6 August, the land irrigated 28 August, plowed 14 November, and sampled on 4 December. We found as the average of two sets of composite samples taken to a depth of nineteen inches, the equivalent of 299.35 pounds sodic nitrate per acre. While the value

of these figures is lessened by the fact that the sample representing the nitric nitrogen present just before harvest was taken in 1913, and the other two in 1914, they still serve to give us a very definite idea of the rate at which the nitric nitrogen is restored to this land after previous removal by a crop, for we can safely assume that the crop of 1914 reduced the nitric nitrogen present at harvest time, 1914, to approximately the same amount that the crop of 1913 had reduced it the previous year. The difference between the amounts of nitric nitrogen in the fallow land and the cropped land on 4 December, 1914, gives us the difference of nitric nitrogen in favor of the fallowed land. This difference is equal to 243 pounds of sodic nitrate. The difference between 299.35 and 101.20 gives us an approximation to the difference in the amount of nitric nitrogen in the top two feet of soil on 1 August and 4 December; this difference is equivalent to 198 pounds of sodic nitrate.

This question was followed more closely in 1915 than in 1913, with equally positive results. The cropped land again contained its minimum amount of nitric nitrogen about 1 August. On 3 August, Section 1800 Red Fife, Check Plot, contained in the surface foot the equivalent of 29.3 pounds of sodic nitrate, on 30 August 42.2, on 22 November 89.1, on 14 December 103 pounds; Section 1900, Red Fife, Check Plot, contained: On 3 August 19.5 pounds, 30 August 50.6, 22 November 73.6, 14 December 121.8. An extended statement of these results is given in tabulated form on a previous page, in which the amount of sodic nitrate corresponding to the nitric nitrogen found is given both for the surface foot and also for the succeeding three feet. This table also exhibits the rapid fall of the nitric nitrogen in the cropped land from the middle of May till the beginning of August, namely, during the growing period of the plant.

The total nitrogen was determined at various times during both seasons. The results for 1913 are given on pages 15, 19 and 23 of Part I, and for 1915 on page 18 of this bulletin. I think it very unsafe to attempt any interpretation of the results, owing principally to the difficulty of obtaining samples of soil which will vary by less than the amounts of nitrogen here concerned; for instance, an actual increase of ten parts per million in any month would mean a percentage difference of one one-thousandth, but this would mean, if converted into sodic nitrate or calculated as proteid matter, 240 pounds for each four million pounds of soil. We sampled 150 square feet of soil, taking a core from the center of each square foot to a depth of one foot, and it was rarely the case that contiguous square feet of soil showed so small a difference in total nitrogen as 0.001 percent. On the other hand, this difference actually reached 0.0354 percent, or more than 35 times as much as would have a very considerable significance in the development of the crop if

present in the form of nitric nitrogen. It is for this reason that I have preferred to state the fixing power of this soil as found by laboratory experiments.

We have not been able, up to the present, to follow the study of the bacteriology of this soil further than was given in Part I.

The study of the composition of the plant, and the effects of the fertilizers, have been presented, together with a general statement of the weather conditions for the two seasons.

One of the first, important questions in our study, especially under our conditions, is: What is the effect of different amounts of water applied to the soil? Others have studied this question in relation to the production of dry matter, but not, so far as I know, as touching the composition of the plant. This question is important in our study, but is incidental to it, for this reason we have prosecuted it only so far as seemed advisable to determine its influence in a general way. We found no differences in the amount of nitrogenous compounds in the plants that could be attributed to the varying amounts of water applied.

This statement is based on two series of samples which have received 31 inches of water in all, 24 inches irrigation and 6.77 inches rainfall, compared with 16 series grown with 19 inches of water, 12 inches irrigation and 6.77 inches rainfall. I am speaking of the plant at this time, but I shall present the effect of different quantities of water applied to the soil on the composition of the kernels, at another time. This question was presented in another form in 1915, when a series of light rains, amounting to about 13 inches during the growing season, kept the plants wet a great portion of the time and further caused very heavy dews, so that the plants, not the soil, were thoroughly wet by application of water almost daily. The amount of water received by the crop in the two seasons was essentially the same, about 19 inches, but the effects which seem attributable to water, or more accurately stated, to the manner of its application in 1915, are very marked. For the present it may suffice to state that it caused the principal differences in the composition of the plants up to the end of July, at which period another factor, largely the result of this external moisture, began to play a still more important part. This factor was the abundant development of rust. These conditions were unfortunate so far as the size of the crop was concerned, but fortunate for the purpose of our study, though we did not desire to introduce these factors into our problem. The general effect was to suppress all forms of nitrogen present in the plant throughout its growing period, and the same was true of the ash constituents. It seems almost as though this externally applied water had actually caused a leaching out of the very substance of the plant. This does not seem so improbable, especially in regard to the ash constituents, when it is

recalled that it is shown in Part I, p. 42, that 93 percent of the total soluble ash in the air-dried wheat plant can be extracted with water. The size of the plants and the percentage of dry matter in them was not materially different in the two seasons.

The part played by the greater cloudiness and a lower mean temperature in 1915 than in 1913 has not been made out. It is for this reason that I refer to effects that seem attributable to water, or its manner of application in 1915. At the present time, I entertain almost no doubt but that these effects are due to the external application of the water to the plants, or to their having been kept wet for so large a portion of their growing period. There are but two other things that I see, in addition to the cloudiness and mean temperature, that may militate against this view, and they are, the extent to which a living plant may differ from a dead one in the solubility of its constituents, and the possibility that transpiration was retarded to a sufficient extent to have reduced the intake of nitric acid and the non-volatile ash constituents.

The very different weather conditions which prevailed during the two seasons were in reality very fortunate for us, for they served to demonstrate the fact that the observed effects of the fertilizers applied in 1913 are independent of the weather. The weather conditions of 1915 made great differences in both the nitrogen compounds and ash constituents of the plants, but they did not obscure the effects of the nitrate applied upon the total or the proteid nitrogen or the silicon or the ash constituents in general. The same is true in regard to the effects of the phosphorus and the potassium.

The effects of the application of nitrogen was to increase the nitrogen in all parts of the plant; this was uniformly true in the stems, leaves and heads, for both the total and proteid nitrogen, and as positive in the wet season as in the dry one. It increased it in the stems and leaves and less regularly so in the heads. It lowered the percentage of dry matter; it lowered the percentage of silicon; it increased the percentage of potassium, calcium and magnesium as a rule, and increased the total ash, while it exerted no influence upon the amount of phosphorus in the plant. It increased the height of the plant, the length of the head, and the color of the plant, but it did not increase the kernels per spikelet.

Phosphorus seemed to be either indifferent to, or possibly tended to depress, the amount of nitrogen in the different parts of the plant. The same is true of potassium, with a stronger tendency to depress the nitrogen.

Both phosphorus and potassium depressed the phosphorus in the plant. This is true of these elements except in one case, in 1913, in which the plants grown with the application of potassium, contained more phosphorus than those grown on the check plot.

These effects upon the composition of the plant are not changed by the weather conditions. In Colorado Bulletin 205, I pointed out a marked effect produced upon the physical properties of the kernels by the application of nitrogen in the form of sodic nitrate, namely, that it produced flinty and often shrunken kernels. This effect was not changed in our wet season of 1915. Further, we cannot see that the yellow-berry question was materially affected by the weather conditions of 1915 compared with those of 1913.

The attack of rust seemed to materially affect the course of the chemical changes that took place after the early part of August, 1915, compared with those that took place during the ripening period of the plant in 1913.

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A BACTERIAL STEM BLIGHT OF
FIELD AND GARDEN PEAS

BY
WALTER G. SACKETT

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A BACTERIAL STEM BLIGHT OF FIELD AND GARDEN PEAS

By WALTER G. SACKETT

INTRODUCTION

Before the introduction of alfalfa into the San Luis Valley, field peas were grown very extensively as a leguminous crop for feeding purposes. Aside from their value in this role, their use in a crop rotation as a means of restoring partially the soil fertility lost by excessive and continuous cropping with small grains, was soon recognized.

For a number of years peas were used almost exclusively as the forage crop, and the acreage planted was very considerable; however, some five or six years ago, it was found that alfalfa could be grown successfully nearly everywhere in the valley. It succeeded very well for the first two or three years, but in 1914, following a heavy, late spring frost, the crop was attacked by the bacterial stem blight which reduced the tonnage of the first cutting 60 to 80 percent, to say nothing of the injury resulting to the plants themselves. Since then there has been a recurrence of the disease each year with varying degrees of severity. Quite naturally, with the appearance of this new trouble, the feeders may have to turn their attention more largely to field peas, but let us hope not to the exclusion of alfalfa.

Practically all of the cultivated land in the San Luis Valley lies at an elevation of between 7,500 and 8,500 feet, and at this altitude the temperature usually remains cool until well into the summer; frosts may be expected any month of the year. The soil is a sandy loam for the most part, and there is an abundance of irrigating water.

The pea being a lover of cool soil and cool weather, it is difficult to conceive of a location where conditions are better adapted to pea growing than in this old lake basin. For years they have been raised here to perfection without the first complaint of anything in the way of a bacterial, fungous or animal pest. But it is a long road that has no turning, for in the spring of 1915 the peas over almost the entire valley, which includes some 500,000 acres, were attacked by a disease, previously unknown in the community, and which at the time threatened to be even more serious than the alfalfa blight.

At about the same time that complaints were received of this trouble on field peas, a similar blight made its appearance on garden peas in Northern Colorado.

In the pages which follow, will be found a description of this disease and of the microorganism which has been found to be responsible for the trouble.

HISTORY AND DISTRIBUTION

The first occurrence of the disease was noted by Mr. E. H. Thomas, county agent for the San Luis Valley, on May 27, 1915, in the garden of Mr. Wm. Ollinger, Hooper, Colorado. In this instance, garden peas for family use had been planted in soil which had been very heavily manured, and when the vines were 3 to 6 inches high, they began to turn brown, dry up and die. The owner attributed the trouble to too much manure or to excessive alkali. However, Mr. Thomas was inclined to look upon these facts as of secondary importance, and accordingly sent the writer several specimens of affected peas at this time.

The general appearance of the plants, with their characteristic bruised, water-soaked leaves and stems, suggested, at first sight, bacteria as a very probable cause of the trouble, and subsequent experiments have confirmed this supposition.

The next locality where the disease was observed was in Blanca, where, on June 1, 1915, Mr. Thomas found the same trouble attacking field peas; during the next few days he noted the blight in the vicinity of San Acacio, Antonito, Monte Vista and Center. In fact, we are reasonably safe in saying that it was general on the early planted peas over practically the entire valley.

The writer visited the localities mentioned above on June 3 and 4. The peas varied considerably in size, ranging from 3 inches in height to 8 or 10, and in the two days that we spent in looking over the fields, we did not find more than two or three tracts that were entirely free from the trouble. The severity of the attack appeared to differ in the different localities, due possibly to the fact that the infection had progressed more rapidly and was farther advanced in some places than in others; now and then we came across a field where only an occasional plant was affected, but again there were many where it was almost impossible to find a healthy one.

Mr. Thomas visited one of the worst affected fields at Antonito on July 22nd. From the roadside, there appeared to be a full stand of good vines, but upon closer examination it was found that at least one-third of the plants were missing. The average branching of the remaining plants was heavier than normal, there being many with three or more vines, while under ordinary conditions only two would have been present. The old infection had dis-

appeared with the death of the first shoots, and the present crop was largely new growth. The vines were heavily podded and thrifty.

Mr. Thomas also visited a number of fields in the vicinity of Blanca and San Acacio on July 21, 1915. On sandy soil where the supply of moisture was limited, the peas had suffered heavily from blight. In two fields in particular, where the crop was planted on new ground, the disease destroyed fully three-fourths of the plants, but in the same locality on practically the same kind of soil where plenty of moisture was present, especially where an irrigation had been given shortly after the blight appeared, a large majority of the plants either threw out new branches, or, where they were not too badly infected, continued their growth.

The first isolations of the causal organism were made from material collected at Antonito on June 4, 1915.

VARIETIES OF FIELD PEAS

The two varieties of field peas that are planted most extensively in the San Luis Valley are the native White Mexican and the Warshauer.

The Mexican is probably a mixture of Canadian Beauty and Golden Vine with French Grey and possibly a few Early Britain.

The Warshauer is a white pea that has been developed by the Warshauer-McClure Sheep Company, of Antonito, Colorado, by hand picking from peas that were two weeks earlier than the common Mexican. It is supposed that the seed originally planted, when this selection was made, was one of the garden sorts usually considered as, "Earliest and Best". However, the pea has been reared under field conditions and continually hand picked until the Warshauer pea is now a decidedly fixed type. It is a medium-vined early pea which begins to blossom when 6 to 8 inches high, resulting in a good distribution of pods thruout the entire length of the vine.

On June 15, 1915, we received a letter from the Empson Packing Company, of Longmont, Colorado, stating that they were sending us some pea vines which appeared to be attacked by a blight. They said further that nothing of the kind had ever occurred before in the history of their canning business, and that altho the first traces had been noted only three or four days previously, the trouble was spreading rapidly. Already a number of fields were affected, and no little alarm was expressed over the possible outcome.

This outbreak of the disease on garden peas, contemporaneous with that on field peas in an entirely different part of the State,

more than 300 miles distant and at an altitude 2,500 feet lower, was of more than passing interest. This led the writer to visit the Longmont section on June 21, in company with Mr. H. J. Cains, of the Empson Company. We found the garden peas affected in the same identical manner as the field peas in the San Luis Valley.

One field of about 12 acres was in very bad condition. The attack was well advanced and general; the vines were watery, olive-green to black in color; many were entirely destroyed, their growing tips curled and dead; others were green and in blossom, while some bore small pods. It was practically impossible to find a perfectly healthy plant in the whole 12 acres. The crop of shelled peas from this field was estimated at 50 percent. This same land was in peas the preceding year, but no disease was observed.

The blight was present, but to a lesser degree, in an adjoining tract of approximately the same size. In both cases the Alaska pea had been planted, the sowings having been made between the 15th and 20th of April.

A few infected plants were found in each of two other fields of the same variety of a somewhat later sowing.

A careful examination was made of several other Alaska plantings which were sown from ten days to two weeks later than any of the above, but in no instance did we find any of the trouble.

In addition to the Alaska, which is the earliest pea planted by the Empson Packing Company, two later sorts are grown for canning purposes. A diligent search for the disease on these later varieties failed to show even a trace.

A number of gardens in Fort Collins experienced a mild attack of blight on the early peas, but in no case was it sufficiently serious to cause any appreciable loss to the crop.

From these observations of one season only, it appears that so far as garden peas are concerned, only the earliest plantings of the early varieties are affected, and that the later sorts are practically free from the trouble.

We have endeavored to ascertain information regarding the distribution of the disease in the Western States, from the respective experiment stations, and up to the present time it has not been observed in Kansas, Montana, Wyoming, Nevada, Idaho, Arizona, or New Mexico. Professor J. J. Thornbee, of the Arizona Station, recalls having seen such a disease in both Nebraska and South Dakota. Professor G. R. Hill, of the Utah Station, reports the trouble as occurring in 1914 at Riverdale, Utah. Professor F. D. Heald, of the Washington Station, has recorded a bacteriosis of peas which may be the same as the Colorado malady. He has very kindly submitted pressed specimens for our examina-

tion, and while it is difficult to reach any definite conclusions from dried material, I am inclined to believe that the Washington disease is different from that which occurs locally.

DESCRIPTION OF THE DISEASE

The disease can be recognized very readily by the watery, olive-green to olive-brown color of the stems, and by the yellowish, bruised and watery appearing stipules and leaflets.

When the blight makes its appearance early in the season, before the plants are more than 8 to 10 centimeters high (3 to 4 inches), one usually finds the stand very uneven and scattering. It is not uncommon to see 4 to 6 feet of drill-row apparently without a single plant, but a closer examination of the ground will reveal the brown and withered remains of what were once small pea vines. Here and there may be located a few stragglers that have not yet succumbed; they usually have several dead leaves next to the ground, while above these are four or five that appear bruised, watery and often ochre-yellow in color. (Right-hand figure in colored plate.) This leaf description applies particularly to the large, clasping stipules, the leaf-like structures at the base of the leaf stalk. (Left-hand figure in colored plate.) The stems of such plants are almost always dark-brown or black and considerably shrivelled, and so far as any further growth is concerned, they are practically dead. Occasionally one meets with a young plant of this kind in which the stem is black next to the ground, but above which both the stem and leaves are normal in color and look perfectly healthy.

In older plants, say 12 to 15 centimeters high, (5 to 6 inches) where infection appears to have taken place at a later period, the stem is watery, olive-green to olive-brown in color (middle figure colored plate); the petioles of the leaves attached to the diseased portion soon become involved, turn watery, olive-green in color, seem to wilt or collapse and allow the leaves to droop; the leaf blades and stipules subsequently appear bruised and watery along the veins and mid-rib, which condition is communicated to the leaf tissue proper, and the whole leaf structure turns a watery, ochre-yellow color, wilts and dies, shrivelled and brown.

So far as our present knowledge goes, the root and that part of the stem which is below ground are not affected.

The infection starts in most cases from 2.5 to 3 centimeters (1 to 1.25 inches) above the ground line and seems to move up the stem toward the growing tip. This is evident from the facts both that the discoloration on the lower part of the vine is nearly always darker than that higher up, indicating an older lesion, and that the lower leaves are the first to die.

Under ordinary field conditions, a single pea plant branches at its base to form two or three principal vines. If the blight attacks and destroys one or more of these, the plant will usually throw out from three to five new ones, from the region below the diseased area, providing sufficient vitality remains to promote this growth. As a matter of fact, this is usually what takes place in the field, and, as a rule, the new growth progresses unmolested, altho, occasionally, this too is attacked. The secondary shoots are often small, and do not make the rank and vigorous growth that is characteristic of the earlier ones.

If the vines become diseased when they are small, and the main vine dies before branching has taken place, the chances are that no branches will be formed, and the plant will be killed outright. Sometimes even the older plants behave in this manner.

The leaves may develop the disease independently of any other structure and die before the stems show any trace of the trouble.

Very rarely small droplets of a pale yellow exudate are found on the stems.

The close resemblance in the appearance of alfalfa plants affected with the bacterial stem blight and that of diseased pea vines is a matter of considerable interest. In fact, the symptoms of the disease in the two plants are so similar as to justify one in making the conjecture that it is all one malady, and that one and the same causal agent is responsible for this condition. The pea and the alfalfa, both being legumes, and both grown in the same soil, under the same climatic conditions, and in a locality where the alfalfa blight has been very severe, the natural inference would be that both plants were suffering from the same cause. This is not the case, however, since the organism which we have isolated from the diseased pea vines and which we have been able to show is the specific cause of the pea trouble, is a separate and distinct form differing both morphologically and culturally from *Ps. medicaginis*, the alfalfa blight organism.

If fragments of the watery, olive-green tissue from either stem, leaf or petiole are mounted in a drop of water on a glass slide, there soon appears about the specimen a milky cloud easily visible to the naked eye. Under the low power of the microscope this resolves itself into a finely granular mass which flows out in all directions in long streamers, so characteristic of infections of this sort. Under the high power, the microorganisms which make up the milky cloud are readily distinguishable as moderately motile rods from two to four times as long as broad.

HISTOLOGY OF THE DISEASED TISSUE

Celloidin sections of diseased stems, killed in absolute alcohol, show the substomatal chambers to be packed with bacteria and

many of the surrounding cells of the underlying parenchyma to be filled likewise. (Fig. I.) The infection appears not to extend into the medullar parenchyma, stereome, or vascular bundles. Neither in the field nor when artificially inoculated in the greenhouse, have we observed the vines, as a whole, to wilt; however it is not uncommon to see the petioles and leaflets in this condition. Frequently plants that have been inoculated artificially show a gradual wilting, or perhaps better designated as withering, in two or three weeks after infection, but not the sudden and complete

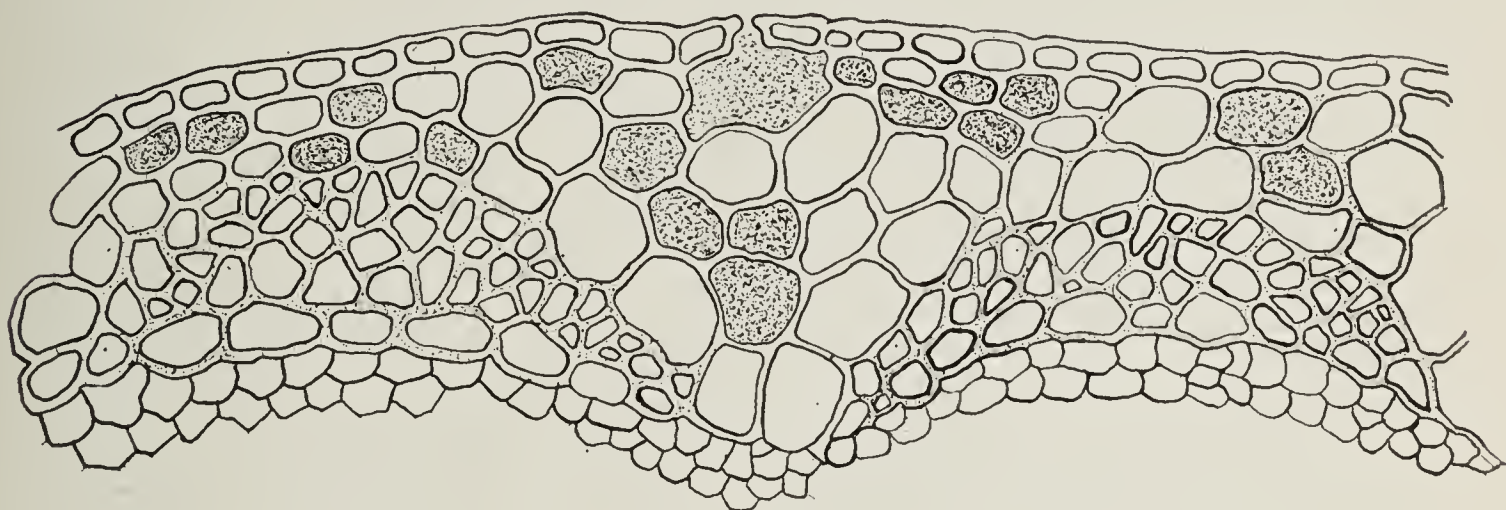


FIG. I

prostration of the entire structure such as is usually meant by the term *wilting* in the technical sense. Owing to the lack of satisfactory histological material, we are unable to say in the latter case whether or not there has been an actual invasion of the vascular system.

ISOLATION OF THE CAUSAL ORGANISM

The material from which the first isolations were made was collected at Antonito, Colorado, June 4, 1915. None of the tissue was given any preliminary sterilization previous to plating, but care was exercised not to use any that was clearly and unquestionably contaminated by soil or otherwise. Dilution plates were made June 5th in +10 nutrient agar, three plates being used in each case. These were incubated for 60 hours at 28° C., at the end of which time colonies were plainly visible.

ORIGINAL ISOLATIONS FROM FIELD MATERIAL, JUNE 5, 1915

No. 1. Stem.—A recent infection; tissue bright and fresh appearing, but watery and discolored well up on the stem; thin transverse section used for plating taken from near growing tip where disease was just developing. Colonies appeared in 60 hours; grayish white by reflected light, bluish cast by transmitted light.

glistening, raised, structure appears flocculent under hand lens, gyrose under low power, margin undulating, general outline of colony round. Plates pure. Two colonies picked up on agar slants.

No. 2. Petiole from Stem No. 1.—Petiole taken from part of stem where disease was advanced, tissue dark and watery; section 0.5 mm. long, near juncture with stem, removed for plating. Colonies visible in 60 hours; same as those obtained from No. 1, but first two plates contaminated, third plate pure. Made subcultures from two typical colonies.

No. 3. Petiole from Stem No. 1.—Petiole taken from part of stem where disease was just appearing; tissue watery and olive-green in color. Colonies appeared in 60 hours; same as obtained from No. 1; culture pure in second and third plates. Made cultures from two typical colonies on nutrient agar.

No. 4. Leaf Blade from Petiole No. 3.—Material used in plating taken from dark, watery part of leaf blade next to midrib; leaf well up on plant and clean. Colonies appeared in 60 hours; same as preceding; pure in second and third plates. Picked up two characteristic colonies.

No. 5. Stem.—Recent infection; tissue light olive-green and watery. Colonies appeared in 60 hours; same as in preceding isolations; plates pure. Picked up two typical colonies on agar slants.

INOCULATION AND REISOLATION EXPERIMENTS

PEAS

September 21, 1915.—Four varieties of peas were used at this time: Warshauer, Horsford, Alaska and Wellington. The plants were grown in 5-inch pots, one variety to a pot, and were fourteen days old when inoculated.

A 24-hour agar culture of the organism that was isolated from Stem No. 1 was used in this series; the agar growth was worked up in the water of condensation at the bottom of the slant, and the suspension thus obtained was employed as the inoculum. The stems to be inoculated were first scarified lightly with a sterilized scalpel until the surface was slightly moist, and then several loop-fulls of the culture were spread over the prepared spot, 1 to 2 centimeters in length. Following this, the culture was pricked into the tissue with a sterilized needle. Three to four scarifications, 2 to 3 centimeters apart, were usually made on each plant, and one plant thus treated was left in each pot uninoculated for a check. They were sprayed immediately after infection with sterile, distilled

water from an atomizer, and placed under bell jars in subdued north light in the laboratory. The bell jars were removed after 48 hours, but spraying was continued for three days more. On September 27, the plants were taken out-of-doors and left in bright sunshine. The inoculated areas on all plants appeared watery and olive-green in color, as compared with the check four days after infection. By the end of six days, there was little change, except for a suggestion of a watery zone beyond the edge of the scarified areas; the Wellington peas remained unchanged.

When observed on October 5, the watery zone had spread about 4 mm. beyond the scarifications, in all except the Wellington, and tissue removed from this part of the stem swarmed with bacteria when examined under the microscope.

By October 7, all varieties, except the Wellington, had developed the disease without question. It had now spread to the stipules, giving them a watery appearance, and in some cases, had produced a yellowing along the veins just as under field conditions. One leaf, that had been inoculated by a needle prick, had developed a large yellow blotch, such as occur in the field. The yellow, olive-green color and watery character had spread along the stem some distance from the original scar. We had had two hard frosts on the 5th and 7th of October, and the plants had been exposed to both.

October 12, 1916.—After two more heavy frosts, all of the plants were taken up, and a careful examination made. One of the most interesting points brought out in the experiment was the apparent lowering of frost resistance. Without exception, all of the plants in which the disease had made any progress succumbed to the frost and wilted, while every check and all of the Wellington plants stood up bright and fresh and showed no effects of the cold whatever. It would appear from this that the Wellington variety is more nearly immune than any of the others.

Observations October 12, 1915

Warshauer plants.—Check still green. Three plants were inoculated, and all show typical olive-green to brown discoloration. This is not confined to the inoculated areas, but has spread over the whole stem; vines somewhat shrivelled and tissue swarming with bacteria.

Horsford plants.—Check in good condition, still green and little affected by frost. Four plants were inoculated; before frost, the watery, olive-green color had spread over the stems irrespective of the original infection; after frost, the vines are shrivelled and brown, and bacteria are very abundant in the tissue.

Alaska plants.—Check normal. Three plants were inoculated; one has developed the disease in an unbroken lesion 12 centimeters

long from the ground up; the others show the trouble just in the immediate region of the scar. In two of them, the infection has spread from the stem into the stipules, giving them a watery appearance which has become yellowish brown in the older lesions. The frost has shrivelled all the vines except the check. Bacteria abundant in affected tissue.

Wellington plants.—Four plants were inoculated with fourteen scarifications in all. As mentioned above, the frost seems not to have injured them appreciably. Almost no discoloration of the stems has occurred beyond the edge of the scarifications, and the vitality and general appearance of the plants are good. A little shrivelling has taken place where the inoculation was made, but there is no indication that the infection has spread. Bacteria are still present at the edges of the old lesions where the tissue appears darker and more watery, but none can be found in the scar proper. Apparently immune.

INOCULATIONS OF OCTOBER 19, 1915—PEAS

The plants of this series were inoculated by pricking (cluster of stabs) the culture into the stem with a sterilized needle without first scarifying the surface. A 24-hour agar culture of the organism isolated from Stem No. 1 was used. All plants were sprayed with sterile distilled water for four days after inoculation, and kept covered with bell jars for three days.

Observations

Warshawer.—Five plants inoculated, and one check. After four days stems begin to have watery appearance at point of infection; check normal in color. After twenty days, stems dark olive-brown and shrunken, leaves withered and brown, practically dead; check normal.

Horsford.—Four plants inoculated midway of the vine toward the growing tip; one uninoculated check. After four days, sunken watery areas appear around the needle pricks; at the end of eight days, two of the plants are so badly shrunken and collapsed at points of inoculation as to allow the whole of the tips to droop. A microscopic examination of the watery tissue taken 1 cm. from needle prick shows the cells to be gorged with motile bacteria. The two remaining plants are watery and discolored, but have not collapsed. Check shows nothing of this shrivelling or discoloration. Causal organism reisolated from one of the two worst affected plants, q. v. page 18.

INOCULATIONS OF NOVEMBER 25, 1915.—HORSFORD PEAS

All of the inoculations heretofore were made with one of the cultures isolated from Stem No. 1 in June. In order to determine

whether the remaining nine cultures, which were isolated at the same time, were likewise responsible for the disease and still virulent, each of nine Horsford plants was inoculated with a 48-hour agar culture of the respective organisms, to-wit: One from stem (No. 1), two from petiole (No. 2), two from petiole (No. 3), two from leaf blade (No. 4), two from stem (No. 5).

In this case, the bacteria were introduced into the stems by single shallow needle pricks about 1 centimeter apart and were distributed over the younger part of the vine. In addition to this, several leaves on each plant were punctured and the culture smeared over the injured leaf surface. All plants were sprayed with sterile, distilled water immediately after inoculation, covered with bell jars and placed in subdued light. They were sprayed again after 36 hours, and after 48 hours they were uncovered and placed in the greenhouse.

Observations

After four days, each of the inoculated plants shows a decided watery zone around each needle prick in the stem, and all of the leaf infections except the one made with culture from Stem No. 5 are taking perfectly; the leaves appear watery and bruised not only around the needle puncture, but also in isolated spots where the culture was rubbed over the surface; this suggests stomatal infection. The disease seems to be progressing most rapidly in the plant that was inoculated with one of the cultures isolated from the leaf blade. (No. 4.)

Dec. 1, 1915.—The watery, bruised appearance of the leaves is spreading and in some cases the leaves are beginning to curl.

Dec. 3, 1915.—The stem pricks now show up as sunken yellow areas, 3 mm. long.

Dec. 6, 1915.—Stems now dark olive-green and watery, not only around the needle pricks, but continuous over the entire stem where inoculated.

Dec. 7, 1915.—Reisolation made from plant inoculated with culture isolated from leaf blade q. v. page 18.

March 31, 1916.—All inoculated shoots brown and dead; four plants are entirely destroyed and have thrown out no new growth from below; one plant has two new shoots, while the remaining three have one each; none of these is vigorous, due possibly to other causes. Check normal.

INOCULATIONS OF DEC. 17, 1915.—HORSFORD PEAS

Nine different cultures, presumably all the same organism, picked up from colonies which were obtained by plating out tissue from a plant infected in the laboratory November 25 with a pure

culture from a diseased leaf blade, were used in this experiment. Each of nine pea vines, approximately 15 centimeters in height, was inoculated with one of these cultures; the germs were introduced by needle pricks both in the stems and in the leaves. The plants were kept covered with bell jars for 48 hours and sprayed with sterile distilled water at frequent intervals; at the end of this time they were placed in the greenhouse.

Observations

Dec. 21, 1915.—All of the inoculations on the stems seem to have taken nicely, as they show watery, slightly sunken areas around the needle pricks.

Dec. 22, 1915.—The watery zone around the needle punctures more pronounced than the day before; many of the leaves are beginning to show watery spots.

Jan. 3, 1916.—While we are obtaining positive results unquestionably with all nine cultures, two of them seem to be somewhat more virulent than the others, as the disease is progressing more rapidly in the two plants inoculated with these particular strains. The watery spots encircling the needle punctures have coalesced into continuous dark olive-green lesions extending over the inoculated portion of the stems. All appear practically the same, but the area involved is considerably greater in the two cases mentioned above. Some of the leaves are shrivelled, others show watery spots and irregular yellow blotches; growth seems to be checked.

Jan. 31, 1916.—The inoculated shoots on all nine plants are dead and black; three of the plants have thrown out a single new shoot from below and three have responded with two new shoots; three died without producing any new growth at all. Fig. II is a photograph, taken at this time, of the two plants with the two new shoots; note in each case the dried, inoculated, dead vine between the two healthy ones. A third check plant is in the same pot.

INOCULATIONS OF JANUARY 6, 1916.—HORSFORD PEAS

The two cultures which appeared to be the most virulent in the preceding series, and which produced the most typical symptoms of disease in the host were selected for reinoculation in the **present** experiment. For convenience, these may be designated as Numbers 3 and 8.

Four plants, 7 cm. in height, were inoculated with Culture 3 by means of single needle pricks in a line along the stem. Three similar plants were likewise inoculated with Culture 8; 72-hour agar cultures were used in both cases. One check plant was left



FIG. II

in the No. 3 pot. All plants were sprayed with sterile, distilled water, placed in greenhouse under bell jars and protected from bright sunlight by newspapers.

Observations

Jan. 7, 1916.—Sprayed plants; no indication of disease yet.

Jan. 10, 1916.—Removed bell jars and newspapers. All plants, except check, show watery, sunken zones around needle pricks.

Jan. 13, 1916.—The separate watery areas have now coalesced so that the stems exhibit a watery, bruised aspect over the entire section that was inoculated. Both cultures seem to be working equally well. Check still unchanged.

Jan. 24, 1916.—Three of the plants inoculated with Culture 3 are turning yellow and the tips of two are wilting, due apparently to collapsing and girdling of the stems, which are now dark

olive-brown in color thruout their entire length; the fourth plant is reacting positively, but slowly.

Two of the plants inoculated with Culture 8 are still erect, but one is turning yellow and wilting, as described above; the stems of all the infected shoots are dark olive-brown in color.

Feb. 19, 1916. Culture 8.—One plant dead; one plant with inoculated shoot dead and two new shoots; one plant with inoculated shoot dark olive-brown and two new shoots.

Culture 3.—The inoculated shoots of all four plants dead. Three plants have two new shoots, and one has one new shoot.

INOCULATIONS OF FEBRUARY 19, 1916.—HORSFORD PEAS

Thirteen vigorously growing pea shoots about to blossom were inoculated with a 24-hour agar culture of Culture 3 by a line of single needle pricks; a fourth plant was pricked with a sterile needle as a control. The shoots were sprayed with sterile, distilled water and kept covered with a bell jar for 36 hours. When examined at the end of this time, watery zones were visible around each needle prick for more than 1 mm., while the check showed nothing but the hole left by the puncture.

Observations

After four days the watery areas surrounding adjacent punctures had coalesced to such an extent as to produce a solid infection over the whole stem. Control normal.

March 8, 1916.—One whole stem dark olive-green, and infection has spread over entire shoot; the disease has not spread as rapidly over second shoot, due possibly to the fact that the inoculation was in older tissue; third vine was accidentally broken off. Check normal.

March 31, 1916.—One plant, which was the less affected, has a black stem for 12 centimeters above ground, but it does not appear to be suffering particularly from the disease; it is growing, blossoming and seems vigorous. The inoculation in this case was on the lower part of the stem in rather old, hard tissue, and as has been observed repeatedly, infections in the older tissue do not have the same disastrous effects as when they are made in the younger. The second plant was inoculated a little higher up, and while in practically the same condition as the other, it is not as vigorous.

INOCULATIONS OF MARCH 9, 1916.—HORSFORD PEAS

To make certain that our stock culture of Culture 3 was remaining pure, it was replated March 4, 1916, and a new culture picked up from agar colony March 8.

In order to verify the new culture, it was inoculated from a 24-hour agar streak into two pea vines that were in blossom. One shoot was pricked with a sterile needle for a check. All plants were in the same pot. They were sprayed as usual and covered with bell jar and newspaper for 48 hours. Placed in greenhouse.

Observations

March 13, 1916.—All inoculations are taking; sunken watery areas, 3 mm. in diameter, around each needle prick, and where these are close together the lesions have coalesced, making a continuous infection the entire length of the stem.

March 31, 1916.—Inoculated shoots dark olive-brown, watery, and shrivelled; discoloration and watery appearance extends from stems along mid-ribs of stipules, causing a partial wilting of the latter. Dark, watery spots also present on leaves and stipules, which suggest stomatal infection probably resulting from washing germs from inoculated stems onto leaves while watering. Both infected vines have a sickly, pale-yellow color and are partially wilted. The check plant shows infection in two spots where the culture has apparently dripped during watering.

April 14, 1914.—All shoots brown and dead, including check, from lowest point of inoculation out to the growing tip; lower part of vines green.

INOCULATIONS OF MARCH 23, 1914

The purpose of this series was to determine whether the organism which is responsible for the pea disease is likewise pathogenic for other common legumes. Twenty-four hour agar cultures were used in all of the infections. In addition to needle prick inoculations in the stems and leaves, the entire plants were sprayed with a suspension of the culture in physiological salt solution. Just previous to this operation, they were thoroly sprayed with distilled water and then with the culture, until the liquid dripped from the leaves. Our object in spraying with the culture was to determine whether the stomata might not serve as a channel of infection, as well as mechanical injuries. All plants were sprayed with distilled water at frequent intervals and kept covered with bell jars for 48 hours after inoculations.

Horsford Garden Pea.—After four days, characteristic watery, olive-green depressions appeared around the needle pricks. After six days, splendid stomatal infections, appearing as dark, watery, green spots, developed on the leaves which had not been subjected to mechanical injury. (Plate II, Fig. 1.)

Golden Wax Bean.—After four days, there appeared around the needle pricks on the bean pods, grayish brown patches, .95 mm.

in diameter. Similar injury with a sterilized needle did not produce the same results. Inoculated stems and leaves were unchanged.

April 14, 1916.—The spots on the bean pod remained unchanged and there was no evidence of the disease in any other parts of the plants.

Alfalfa.—April 14, 1916.—The plants appeared to be entirely immune to the disease.

Sweet Clover.—April 14, 1916.—Entirely immune.

Crimson Clover.—April 14, 1916.—Entirely immune.

Mammoth Clover.—April 14, 1916.—Entirely immune.

Cow Pea.—April 14, 1916.—Entirely immune.

REISOLATION OF CAUSAL ORGANISMS FROM PLANTS INOCULATED WITH PURE CULTURES

First Reisolation, October 27, 1915

Platings in nutrient agar were made from sections taken from pea stems which had been inoculated October 19 with a pure culture from Stem No. 1 and which had developed the blight with all the typical symptoms. The tissue used came from two different parts of the vine where it appeared watery and olive-green in color some distance from the point of infection. No attempt was made to sterilize the surface of the stems from which this was taken, previous to plating. The plates gave a pure culture, and from the resulting colonies, eighteen were picked up on agar slants; ten of these were selected and reinoculated into Warshauer field peas November 15. Typical blight resulted in every case.

Second Reisolation, December 7, 1915

The plant from which the reisolation was made was inoculated November 25, 1915, with one of the cultures originally isolated from an infected leaf blade, June 4, 1915.

Two sets of plates were made from this plant, one from the stem and one from the base of a watery petiole where the disease was just starting. The stem was yellow, watery and sunken over the whole area of needle pricks, not only around them, but between, as well.

In all former isolations, no precautions were taken to sterilize the outside of the stems previous to plating out the tissue. However, in the present case it was wiped with alcoholic mercuric

chloride, 1-1000, after which a section to be plated was removed with a sterile scalpel. It was next transferred to alcoholic mercuric chloride (1-1000) for 15 seconds, then washed in three changes of sterile, distilled water. From the distilled water it was transferred to a tube of nutrient broth where it was crushed, and dilution plates were made from the suspension thus obtained.

The second set of plates was made directly from the watery petiole without any previous sterilization.

Pure cultures of the original organism were obtained from both sets of plates in the second and third dilutions; the colonies in the first dilution were so numerous, that it was impossible to tell anything about their purity.

Three colonies were picked up from the first set of plates and six from the second, making nine pure cultures in all, of presumably the same organism.

On December 17, these were all inoculated into pea plants, as described before on page 13 with positive results.

DESCRIPTION OF THE CAUSAL ORGANISM

Pseudomonas pisi, n. sp.

History.—The microorganism herein described as the cause of a bacterial stem blight of field and garden peas, and to which the writer has given the name *Pseudomonas pisi*, n. sp., was isolated June 4, 1915, from the watery portion of a diseased leaf blade. It was grown upon +10 nutrient agar until November 25, 1915, when it was inoculated into a pea plant, where it produced all of the symptoms characteristic of the disease. On December 7, 1915, a reisolation of the organism was accomplished, and after replating to insure purity, it was again inoculated into peas on December 17, 1915, January 6, 1916, February 19, 1916, March 9, 1916, and March 23, 1916. In every case, positive results have been obtained. The culture which has been used in the following species description came from the same stock as that used in the plant inoculations of December 17.

I. MORPHOLOGY

I. VEGETATIVE CELLS.—As the organism occurs both on culture media and in the plant, it is a short rod with rounded ends, mostly single and in pairs (Plate I, Fig. 1), but occasionally in fours and sixes; filaments have been obtained from very young agar cultures 10 to 97 μ in length. (Plate I, Fig. 2.) The individual rods measure 1.11 to 3.28 μ long and .58 to .82 μ wide. The length of the majority is 2.26 μ and the width, .68 μ .

2. ENDOSPORES.—No spores have been observed. Agar cultures 6 days and 48 days old were stained for spores both with Moller's stain and with Zeihl-Nielson carbol fuchsin, with negative results.

3. FLAGELLA.—The organism is motile by means of a single polar flagellum readily demonstrable in 18-hour agar cultures stained by Loeffler's method. According to Migula's classification, this places the organism in the genus, *Pseudomonas*.

4. CAPSULES.—No capsules could be demonstrated either by Welch's method or by that of Hiss.

5. ZOOGLOEA.—No zoogloea have been observed.

6. INVOLUTION FORMS.—None observed.

7. STAINING REACTIONS.—The germ stains readily with all of the ordinary aqueous stains. Both aqueous and carbol fuchsin bring out the coarsely granular protoplasm of the cell, together with what appear to be polar bodies. Loeffler's methylene blue shows nothing unusual altho at times there is a suggestion of irregular staining. Neisser's stain reveals neither polar bodies nor any special intracellular structures. It is Gram negative and is not acid fast. Neither starch nor glycogen were demonstrated. Both anilin-water genitan violet and anilin water fuchsin stain it readily.

II. CULTURAL FEATURES

1. AGAR STROKE.—*Growth* moderate in 24 hours; abundant in 4 days. *Form of growth*—filiform, margins irregular. *Elevation*—flat. *Lustre*—glistening. *Topography*—smooth. *Optical characters*—translucent. *Chromogenesis**—grayish white, Engine Color No. 13. *Odor*—decided, rotten cabbage. *Consistency*—butyrous. *Medium*—slightly greened.

2. POTATO.—*Growth*—moderate, persistent. *Form of growth*—filiform. *Elevation of growth*—slightly raised. *Topography*—smooth. *Odor*—absent. *Chromogenesis*—cream, orange yellow tint No. 2 in three days, Engine color No. 7 in five days (light orange). *Consistency*—waxy and slightly viscid. *Medium*—gray-brown in fourteen days.

3. LOEFFLER'S BLOOD SERUM.—*Stroke*—moderate in 72 hours. *Form*—filiform. *Elevation*—slightly convex. *Lustre*—glistening. *Topography*—smooth. *Chromogenesis*—pale yellow, Engine color 3a. No liquefaction. *Medium* unchanged.

*Color terms refer to Standard colored papers made by Milton Bradley Co., Springfield, Mass.

4. GLYCERINE AGAR.—*Growth*—abundant. *Form of growth*—filiform. *Elevation of growth*—slightly raised. *Lustre*—glistening. *Optical characters*—translucent. *Topography*—smooth. *Chromogenesis*—grayish white, Engine color No. 13. *Odor*—soured peas. *Consistency*—butyrous. *Medium*—greened.

5. MANNITE AGAR.—*Growth*—scant, just sufficient to define line of inoculation. *Form of growth*—filiform. *Elevation*—slightly raised. *Lustre*—glistening. *Topography*—smooth. *Optical characters*—translucent. *Chromogenesis*—color of boiled starch. *Odor*—absent. *Consistency*—butyrous.

6. GELATIN STAB.—*Growth*—best at top. *Line of puncture*—filiform. *Liquefaction*—begins in 24 hours; crateriform in 48 hours, broad funnel-shaped in three days (Plate II, Fig. 2), strati-form in seven days. (Plate II, Fig. 3.) Depth of liquefaction in tube 10 mm. in diameter, evenly inoculated, at the end of 30 days at 20° C. was 33.0 mm. Liquefaction in tubes regular size, 150X16 mm. complete after 102 days. *Color* of medium unchanged.

7. NUTRIENT BROTH.—*Surface growth*—scum in five days which becomes heavy, flocculent growth in ten days; sinks on agitation. *Clouding*—strong, persistent, fluid turbid. *Odor*—decided, putrefactive. *Sediment*—scant, compact and finely granular.

8. PLAIN MILK. 28° C.—*Coagulation* delayed until the fourth or fifth day, when a soft, more or less flocculent, curd is formed. *Extrusion of whey* begins in four days. *Coagulum* is slowly peptonized, the digested portion or liquid becoming light yellowish green in color. *Peptonization* begins on fourth day, 82% being digested in 21 days, and is complete on the 52nd. Reaction, 1 d. + 12, 2 d. + 12, 4 d. + 12, 10 d. + 4, 20 d. — 4. *Consistency*—soft curd. *Lab ferment* present.

20° C.—*Coagulation* delayed until the sixth or seventh day, when a soft curd is formed. *Extrusion of whey* begins in seven or eight days. *Coagulum* is slowly peptonized, the liquefied portion becoming pale lumiere green* in color. *Peptonization* begins on the eighth day, 60% of this curd being digested in 21 days and is not quite complete after 58 days. One-hundred c.c. portions in 200 c.c. Erlenmeyer flasks were completely peptonized in 28 days. Reaction 1 d. + 12, 2 d. + 12, 4 d. + 12, 10 d. + 4, 20 d. † *Consistency*—soft curd. *Lab ferment* present.

9. LITMUS MILK. 28° C.—Lavender-colored litmus milk begins to turn blue from the surface downward, becoming lighter

*Color Standards and Color Nomenclature—Ridgway.

†The development of by-products at the end of 20 days interfered so seriously with the determination of the end point that it was practically impossible to ascertain the reaction at this time.

below, and is two-thirds blued after ten days. Following this, the litmus is reduced and the whole tube assumes a gray color in fifteen days. At the end of twenty days the peptonization is complete and the fluid is dark blue to dark blue green in color. Coagulation begins on the fifth day, followed by clearing, which is complete in twenty days.

20° C.—Milk begins to turn blue from the surface downward after seven days, becoming lighter below, and is completely blued after fourteen days. Following this the fluid becomes gray with a blue ring at the surface, and at the end of 35 days it is between dark blue gray and dark green gray, *i. e.* green gray No. 2 and A-blue green dark, in color. Coagulation begins the seventh day, followed by peptonization, which is complete in 35 days.

10. GELATIN COLONIES.—*Growth*—moderately rapid at 20° C. *Form*—round. *Elevation*—crateriform, liquefying. *Edge*—entire. *Liquefaction*—saucer. *Size*—4 mm. diameter in three days.

11. AGAR COLONIES.—*Growth*—moderately rapid at 20° C. *Form*—round. (Plate I, Figs. 3, 4.) *Elevation*—slightly convex. *Edge*—undulate. *Internal structure*—gyrose, marked by wavy lines indefinitely placed. (Fig. III.) *Size of majority*—2 mm. in five days. Deep colonies lens-shaped. (Plate I, Fig. 5.)

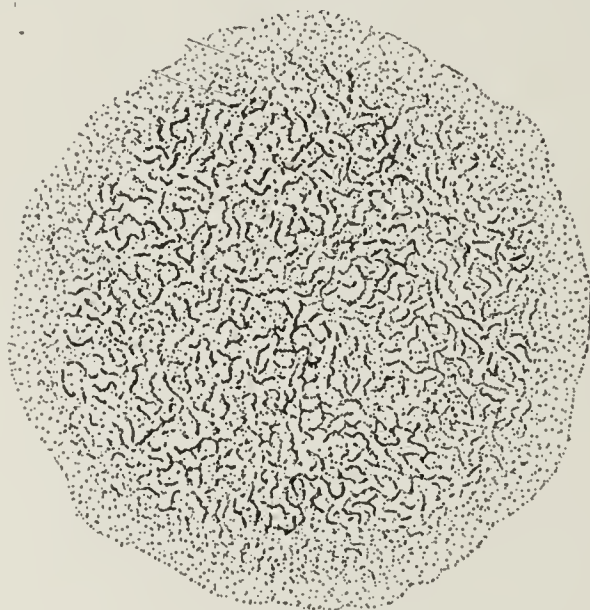


FIG. III

12. STARCH JELLY.—Prepared from Uschinsky's solution and potato starch. *Growth*—moderate. *Medium*—stained yellowish green. *Diastatic action*—absent.

13. COHN'S SOLUTION.—No growth.

14. USCHINSKY'S SOLUTION.—No growth.

15. FERMI'S SOLUTION.—Growth abundant, heavy clouding, white wrinkled pellicle at surface in ten days and small amount of sediment.

16. NAEGLI'S SOLUTION.—Slight transient clouding.

17. FRAENKEL'S SOLUTION.—Heavy clouding and surface scum in ten days.

18. DUNHAM'S SOLUTION.—Uniform, heavy clouding and considerable white compact sediment, somewhat viscid on agitation.

19. ASPARAGIN SOLUTION.—Growth, abundant. Fluid, colored light green.

20. SOHNGEN'S SOLUTION.—(Urea.) No growth.

21. SODIUM CHLORIDE IN BOUILLON.—Nutrient broth containing 1% peptone, but without salt, was used in this determination. To measured quantities of this medium, different amounts of chemically pure sodium chloride were added, giving a range in the salt content from 0.0% to 5.0%. Four tubes of each concentration were prepared, and each set differed from the others by 0.25%. One loop of a 24-hour broth culture was used for the inoculation, and the tubes were kept at 28° C.

Growth occurred in 24 hours in all concentrations up to 2.0%. No difference could be observed in the amount of growth from 0.0% to 0.75%, however, with 1.0% and 1.25% there was less, and with 1.5% and 1.75% there was still less. After 48 hours, growth appeared in the tubes containing 2.0% to 2.75%; after three days in 3.0% and 3.25%; after eight days one of the set with 3.5% became turbid. Beyond this point no growth took place, 3.75% being sufficient to prevent growth.

The detailed results of this experiment are given in Table I.

TABLE I
The Effect of Sodium Chloride upon Growth in Bouillon

%NaCl	Days Before Growth Appeared														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
.50	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
.75	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1.00	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1.25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1.50	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1.75	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.00	—	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.25	—	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.50	—	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.75	—	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3.00	—	—	+	+	+	+	+	+	+	+	+	+	+	+	+
3.25	—	—	+	+	+	+	+	+	+	+	+	+	+	+	+
3.50	—	—	—	—	—	—	—	+	+	+	+	+	+	+	+
3.75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

22. GROWTH IN BOUILLON OVER CHLOROFORM.—To 10 c.c. of nutrient broth in test tubes, 5 c.c. of chloroform were added with aseptic precautions. Duplicate tubes thus prepared were inoculated with one loop of a 24-hour broth culture and held at 20° C. No growth took place in the tubes containing the chloroform after 60 days, while a check tube of plain broth gave abundant growth in 24 hours.

23. NITROGEN.—Peptone, asparagin, urea and ammonium tartrate have been used in different media as a source of nitrogen for the organism. Nitrogen was obtained very readily, as would be expected, from the first of these, as it occurred in nutrient broth, nutrient gelatin, nutrient agar and Dunham's solution. Good growth was also secured from the nitrogen of the asparagin present in Jordan's asparagin solution.

Jordan's Asparagin Solution

Redistilled water.....	1000 c.c.
Asparagin	2 grams
MgSO ₄	1 gram
K ₂ HPO ₄	1 gram

No growth was obtained from either the urea nitrogen in Sohngen's solution, or the ammonia nitrogen in the ammonium tartrate of Cohn's solution.

Sohngen's Solution

Tap water	500. c.c.
Urea	25. grams
K ₂ HPO ₄	.25 gram
Calcium malate	2.50 grams

24. BEST MEDIA FOR LONG-CONTINUED GROWTH.—Standard nutrient agar +10.

25. QUICK TESTS FOR DIFFERENTIAL PURPOSES.—Liquefaction of gelatin; coagulation and peptonization of plain milk; growth in Fermi's solution, absence of growth in Uschinsky's and Cohn's solutions; production of acid from dextrose, galactose and saccharose in sugar free broth; yellowish-green color produced in starch jelly.

III. PHYSICAL AND BIOCHEMICAL FEATURES

I. GAS PRODUCTION.—The power of the organism to produce gas from dextrose, galactose, saccharose, mannite, laevulose, maltose, inulin, lactose and glycerine was determined by adding 1% of the different fermentable substances to +10 sugar free bouillon. Two fermentation tubes of each were prepared, and after sterilization, they were inoculated with a 72-hour agar culture and placed in an incubator at 28° C. *No gas was formed in any case.* No growth occurred in the closed arm, and there was a sharp line of demarcation between the growth in the upper part of the U and the closed arm. After fourteen days the reaction of the different inoculated broths was tested with litmus, and it was found to be acid in the case of glucose, galactose and saccharose, and alkaline in the remainder.

2. AMMONIA PRODUCTION.—Nutrient bouillon containing 1% peptone and Jordan's asparagin solution with 0.2% asparagin were used in determining the power of the organism to produce ammonia. Duplicate 100 c.c. portions of each solution in 250 c.c. Erlenmeyer flasks were inoculated with two loops of a 24-hour broth culture and kept at 20° C. Uninoculated controls of each solution were carried along with these at the same time. After five days, both cultures and controls were analyzed for ammonia by distillation with mag-

nesia. The asparagin solution yielded considerably more ammonia than the nutrient bouillon. The results follow :

TABLE II
Ammonia Production

Nutrient solution	Milligrams N as NH ₃ in 100 c.c. culture after 5 days	Milligrams N as NH ₃ in 100 c.c. sterile culture solution	Milligrams N as NH ₃ produced by the micro- organisms
Nutrient bouillon...	15.1308	9.03645	6.09435
	15.2709		6.23445
Asparagin solution..	27.4596	0.9807	26.47890
	29.0707		28.09000

3. NITRATES IN NITRATE BROTH.—Nitrates are not reduced after five days either at 20° C. or 28° C.

4. INDOL PRODUCTION.—Neither indol nor the cholera red reaction is produced in Dunham's peptone solution after 10 days at 20° C.

5. ACID PRODUCTION FROM SUGARS AND GLYCERINE.—One hundred c.c. portions of +10 sugar free broth to which 1% of the different fermentable substances was added were inoculated with two loops of 24-hour broth culture and kept at 20° C. Five c.c. were taken from each flask with a sterile pipette daily and the reaction to phenolphthalein determined with n/10 NaOH or n/10 HCl. The titrations were made by adding the 5 c.c. of the sample to 45 c.c. of hot, freshly boiled distilled water, rather than by boiling the sample with the water. This was done in order to avoid the loss of any volatile acid that might be present. At the end of ten days there was a slight increase in the acidity of the broths containing saccharose, galactose and dextrose, from +10 to +13, altho in all probability this does not begin to represent the actual amount of acid produced, since considerable quantities must have been neutralized by the ammonia which we know is formed. The remaining broths were more alkaline at the end of the ten days than at the beginning. The detailed titrations are given in Table III.

TABLE III
Production of Acid from Sugars and Glycerine

250 c.c. Erlenmeyer flasks containing 100 c.c. sugar- free broth and 1 percent	Reaction in degrees Fuller's scale after given number of days										
	0	1	2	3	4	5	6	7	8	9	10
Check	10	10	9	7	6	5	5	5	4	1	—2
Dextrose	10	10	10	10	9	9	9	9	11	13	13
Galactose	10	10	10	9	9	10	11	11	12	13	13
Saccharose	10	10	10	8	8	9	9	11	12	12	13
Mannite	10	8	8	8	6	5	4	4	4	2	—5
Laevulose	10	8	8	8	6	6	5	4	4	4	0
Maltose	10	8	8	6	6	5	5	5	3	—2	—2
Inulin	10	8	6	6	6	6	5	5	3	3	—3
Lactose	10	10	10	7	6	6	5	5	5	1	—4
Glycerine	10	8	8	8	5	5	4	4	4	4	4

6. HYDROGEN SULPHIDE PRODUCTION.—No hydrogen sulphide is produced. This was determined by means of both iron gelatin and nutrient broth.

In the former case, stab cultures were made in +10 nutrient gelatin which contained 0.5% of iron potassium tartrate. No blackening took place along the line of the stab as the result of the formation of iron sulphide.

In the second method of determination, tubes of nutrient broth were inoculated and held at 28° C. After 24 hours, strips of filter paper, moistened with lead acetate were suspended in the tubes above the fluid; these were remoistened each day for five days, but after fifteen days no blackening of the paper had taken place, due to the formation of lead sulphide.

7. TOLERATION OF ACIDS.—The toleration of acids is slight. We have determined this point with relation to citric, malic, oxalic and tartaric acids by adding different amounts of these to neutral nutrient bouillon in quantity sufficient to give the broth the acidities +15, +30 and +45. Three tubes of each acidity were prepared from each acid. They were inoculated with one loop of a 24-hour broth culture and subsequently kept at 28° C. In 24 hours, the +15 tubes of all the acids were uniformly turbid, but none of the others gave any growth. After twenty days the results remained unchanged.

Hydrochloric acid added to nutrient broth sufficient to give it a reaction of +27 inhibits growth.

8. TOLERATION OF ALKALIES.—So far as our studies go, the toleration of alkalies is even less than that of acids, altho this point has been determined for only one alkali, NaOH. Sodium hydroxide added to nutrient broth sufficient to give it a reaction —11 inhibits growth.

9. OPTIMUM REACTION.—The optimum reaction for growth in nutrient broth appears to be about +8. This was determined by adding to 20 c.c. portions of sterile broth, with aseptic precautions, sufficient normal NaOH or HCl as the case required, to give a series of broths ranging from +41° to —17° and differing from each other by 2 degrees. The contents of each flask were distributed into four sterile tubes by means of sterile pipettes, and without further sterilization, three of each set were inoculated with one loop of a 24-hour broth culture. The fourth tube of each set was kept uninoculated as a check against possible contamination, but in no case did any of these develop growth. The inoculated tubes were kept at 28° C.

After 24 hours, growth was present from +21 to —5, in 48 hours, it appeared in —7, and in 72 hours in +23, in 7 days in —9.

and in 12 days in +25. Beyond these points no growth took place, from which we may conclude that the limits of growth are from —9 on the alkaline side to +25 on the acid.

After 72 hours there was a marked difference in the degree of turbidity in the different tubes. From +5 to +11 the growth was best; from +13 to +19 there was a gradual decrease, and beyond +19 there was an abrupt falling off. Going in the other direction, there was a heavy growth in +3, but not as good as in +5; in +1 the turbidity was not as decided as in +3, and beyond this there was an abrupt drop.

From this, it appears that conditons for growth became very restricted beyond +19 on the one side and beyond +1 on the other, and altho growth was not entirely inhibited until +27 was reached in the one direction and —11 in the other, the optimum reaction seems to lie between +5 and +11, probably about +8.

10. VITALITY ON CULTURE MEDIA.—Long. By transplanting the culture once every two weeks on nutrient agar, no difficulty has been experienced in keeping it alive and active for ten months.

11. TEMPERATURE RELATIONS.—The thermal death point lies between 49° C. and 50° C. Ten c.c. portions of nutrient broth in thin-walled test tubes of uniform diameter (16 mm.) were inoculated with one loop of a 24-hour broth culture, and after allowing three to five minutes for thoro diffusion, four tubes for each temperature considered were plunged into water of the desired temperature up to the plugs. They were left there for exactly ten minutes and then immediately cooled in cold water. The water in the bath where the determinations were made was kept in constant motion, thus insuring a uniform temperature, by a horizontal paddle operated by a water motor. The effect upon growth was determined for each degree of temperature from 45° C. to 55° C. Good growth took place in all tubes heated up to and including 49° C., but none occurred beyond that.

Optimum temperature.—The best growth was obtained between 27° and 28° C. No growth takes place at 37½° C.; good growth occurs at 20°, but it is not as abundant as at 28°. At 7° C., sufficient growth results in 48 hours to define the line of inoculation on an agar streak, while in two weeks the growth is about the same as a 24-hour culture at 20° C., *i. e.* moderate.

12. EFFECT OF DRYING.—The organism is rather resistant to drying. Flamed cover-glasses were spread thinly with a suspension of a 24-hour agar culture in distilled water and allowed to dry in the air. They were afterwards placed in sterile, covered petri-dishes, and every 24 hours for a period of 22 days, two of

these were transferred to tubes of nutrient broth. There was considerable irregularity in the way these grew after different periods of drying, due presumably to the unevenness of the suspension. Up to 13 days drying, growth was fairly uniform, but none occurred again until the 18th day and then not until 21 days. No growth took place with the films dried for 22 days, but as none was dried longer than this, we can only say that 21 days dessication, under experimental conditions, was not sufficient to kill the organism.

13. PERCENT KILLED BY FREEZING.—(Salt and crushed ice.) The organism is relatively sensitive to freezing. From a 100 c.c. bouillon culture, 24 hours old, 10 c.c. were placed in each of four tubes of uniform diameter. These were packed in crushed ice and salt, frozen solid and kept frozen for 15, 30, 45, and 60 minutes respectively.

As soon as the specified time was up, each tube was thawed at once by placing it in cool water (four to five minutes required) and when entirely liquefied, dilution plates were made in +10 nutrient agar. Before freezing, dilution plates were made from the original culture as a check. Plates were kept at 20° C. and colonies counted after four days.

The original culture contained 19,800,000 bacteria per c.c. Eighty-five and 85/100 percent (8.85%) were killed by 15 minutes freezing; 93.03% by 30 minutes; 95.75% by 45 minutes, and 95.73% by 60 minutes. The number present after freezing 45 and 60 minutes is practically the same, altho the figures are slightly larger for the 60-minute tube; this is probably nothing more than an error due to dilution. The detailed results are given in Table IV.

TABLE IV
Sensitiveness to Freezing

Length of exposure to freezing temperature	Dilution	No. bacteria per c.c. after freezing	No. bacteria killed per c.c.	Percent killed
Check not frozen.	1-100,000	19,800,000	0	0
15 minutes	1-100,000	2,800,000	17,000,000	85.859
30 minutes	1-10,000	1,380,000	18,420,000	93.03
45 minutes	1-10,000	840,000	18,960,000	95.758
60 minutes	1-10,000	845,000	18,955,000	95.732

14. SUNLIGHT.—The organism is rather sensitive to the germicidal action of sunshine.

Flamed cover-glasses were spread thinly with a suspension of a 24-hour agar culture in distilled water and dried in the air. They were then exposed, germ side up, in covered petri-dishes to the bright sunshine. At the end of 15, 30, 45 minutes, 1, 1.5, 2,

2.5 and 3 hours, respectively, two cover-glasses were removed and dropped into tubes of sterile broth which were then inoculated at 28° C. Growth resulted from all exposures up to and including 2 hours, but none took place with the 2.5 and 3-hour slips. The experiments were made at Fort Collins, Colo., January 21, 1916, beginning at 10:55, a. m. and ending at 1.55, p. m.

Thinly sown agar plates, with one-half of the bottom covered with black paper were exposed to bright sunshine, bottom up, on a bed of crushed ice for 15 minutes. Exposure made February 24, 1916, 2:05 to 2:20, p. m. After exposure, the plates were held at 20° C. for four days and the colonies that developed counted. An average count of five plates showed that 33.2% of the organisms were killed by an exposure of fifteen minutes under the conditions of the experiment. The detailed results are given in Table V.

TABLE V
Effect of Sunlight

No. colonies exposed half of petri-dish	No. colonies covered half of petri-dish	Gain of covered over exposed	Percent killed by sunlight
21	30	9	30
22	38	16	42
28	46	18	39
24	32	8	25
25	36	11	30

15. RELATION TO OXYGEN.—The organism is an obligative aerobe. Duplicate inoculations upon agar slants and thickly sown agar plates were placed in Novy jars, and a stream of hydrogen was allowed to flow thru them for two hours, after which they were sealed. After fifteen days no growth had taken place on either slants or plates. When returned to the air, abundant growth followed on both, after 48 hours, showing that the organisms had not been killed, but merely prevented from developing because of lack of air.

Parallel stroke inoculations on agar plates were covered at intervals with flamed cover-glasses so as to exclude all air. No growth whatever occurred beneath the glasses, while abundant growth took place where the air was not excluded.

Further evidence of the aerobic nature of the organism is to be had in its failure to develop in the closed arm of the fermentation tubes.

16. FERMENTS.—A proteolytic enzyme, probably pepsin, and lab ferment are produced. Neither diastase nor invertase is formed.

17. CRYSTALS.—No crystals have been observed.

18. EFFECT OF GERMICIDES.—This has been reserved for a future publication.

IV. PATHOGENICITY

Pathogenic to field peas (*Pisum sativum* var. *arvense*) and garden peas (*Pisum sativum*). Not pathogenic to alfalfa (*Medicago sativa*), sweet clover—yellow—(*Melilotus officinalis*), crimson clover (*Trifolium incarnatum*), mammoth clover (*Trifolium pratense*, var. *perenne*), cow peas (*Vigna unguiculata*), and garden beans (*Phaseolus vulgaris*).

V. GROUP NUMBER

Ps. 211.2322033

FIELD EXPERIMENTS

In conjunction with Mr. E. H. Thomas, of Alamosa, we have endeavored to study the progress of the disease in the field under natural conditions. To this end, Mr. Thomas staked and marked 25 field pea plants, most of which were affected, on June 12, 1915, on the ranch of Mr. W. F. Uray between Monte Vista and Center.

These were observed at frequent intervals during the early summer, and changes in their condition from time to time were recorded as given in Table VI. The disease was most active from June 12 to June 17; on June 24 it had made but little further progress, and by July 1 it had practically disappeared.

Briefly, our study of these plants has brought out three points: First, badly affected shoots, where the infection is within a few nodes of the growing tip, are almost invariably killed outright; second, as a rule, when the original shoots are killed, new ones come up to replace them, except in very young plants; third, if the infection is confined to a few internodes next to the ground, the shoot outlives the disease and its growth is undisturbed.

TABLE VI

Observations on 25 Field Pea Plants on the Ranch of W. F. Uray, Center, Colorado, June 12 to June 24, 1915*

Plant No.	Date of Observation:		
	June 12, 1915	June 17, 1915.	June 24, 1915.
1.	West shoot badly infected; east shoot diseased at base.	West shoot diseased all the way to terminal tendril; still growing. East shoot diseased to second branch; growth** $\frac{1}{2}$ inch.	West plant ceased growing and throwing up new shoots 3 inches high. East plant, growth 2 in.
2.	Shoot to east—first 6 internodes badly diseased; trace on 8th and 10th; another shoot of same plant affected just on 1st internode; another shows trace.	East shoot dead; 2nd shoot diseased over 1st 7 internodes and traces on 8th and 9th; 3d, just at base; 2nd and 3d growing.	New branches starting which have made 4-inch growth — old unchanged shoots.
3.	Slight infection at base.	Looks thrifty but infection solid over 5 internodes and on branch at 8th node; $\frac{3}{4}$ in. growth.	No advance in disease; whole vine growing—3 in.
4.	Slight infection at base of one shoot and others normal.	Infected shoot shows disease over 6 internodes, $\frac{1}{2}$ in. growth; normal shoot 3 in. growth; 1 dead shoot and 2 others affected over 4 internodes.	Four-inch growth on all shoots.
5.	East vine infected on 4 internodes; west not; just starting to branch.	East vine infected over 6 internodes, growth $1\frac{1}{4}$ in.; 2 new branches have developed; west shoot normal.	East plant blooming—growth 2 in.; normal.
6.	One shoot infected on first 3 internodes.	Diseased on first 6 internodes; growth 4 in.	No growth, although infection is not spreading.

*Observations of June 12 and 24 made by Mr. Thomas.

**The growth recorded refers to growth since last observation.

TABLE VI—Continued

Observations on 25 Field Pea Plants on the Ranch of W. F. Uray,
Center, Colorado, June 12 to June 24, 1915

Plant No.	Date of Observation:		
	June 12, 1915.	June 17, 1915.	June 24, 1915.
7.	Normal, no disease.	Stem and leaves both diseased on first 5 internodes. Many separate leaf infections; growth, 1— $\frac{3}{4}$ in.	Practically no changes.
8.	Not diseased, but inoculated by pricking into stem with knife infected from diseased plant. Second shoot pricked with knife before contamination.	Stem shows decided watery yellowish patches where inoculated. Check plant normal; growth 2 in.	Inoculated plant shows disease over 6 internodes; growth 2 in. Four new shoots coming up. Check plant normal; growth 4 in.
9.	Slightly infected, no marked discoloration.	Seven internodes involved, watery new shoots starting; $\frac{1}{2}$ in. growth.	Disease has not spread; growth 6 in., new shoots appeared, 1 in. long.
10.	Two shoots normal.	One shoot very badly involved, other normal, with $2\frac{1}{2}$ inch growth.	Diseased shoot practically dead; other branch normal; $2\frac{1}{2}$ in. growth.
11.	Entire clump of shoots infected.	All shoots sickly; $\frac{1}{4}$ in. growth.	Disease checked; growth 5 in.
12.	Normal.	Normal; growth 2 in.	Normal; growth 2 in.
13.	Badly infected up to 5th internode, inclusive.	Infected over 7 internodes; growth $\frac{3}{4}$ in. New shoots developing.	No growth; 1 new shoot dead and 3 others just starting.

TABLE VI—Continued

Observations on 25 Field Pea Plants on the Ranch of W. F. Uray,
Center, Colorado, June 12 to June 24, 1915

Plant No.	Date of Observation:		
	June 12, 1915.	June 17, 1915.	June 24, 1915.
14.	In reality 2 plants, red and white stem; disease just showing.	Red vine—3 shoots: 1 dead, 1 healthy, 1 infected on 6th internode; no growth. White vine, traces just showing on petiole of bottom leaf; 1 in. growth.	Red vine—2 shoots growing, 2½ in. White plant — no spread of disease; 4-in. growth.
15.	Three shoots, slight traces.	One shoot dead, 2nd small, badly infected, 3d with traces on 3d and 4th internode; branch at 4th node diseased; growth 3 in.	Second, dead; 3d, has grown 6 in., disease on 4th internode inactive.
16.	Normal.	Slight leaf infection on leaves at base; growth, 2½ in.	Disease has not spread; growth 2 in.
17.	Two diseased plants.	South plant diseased and watery to 9th node, new shoot starting, no growth. North plant, 4 branches: 1 dead, 1 badly affected, 2 normal; no growth. Red stem.	Original plants dead; 1 new shoot 8 in.
18.	Clump of small yellow shoots; badly diseased; nearly gone.	Practically dead; new shoots coming.	Original plants dead, 1 new shoot 8 in.
19.	West plant diseased; east normal.	West plant, petiole at 4th node affected, growth 1 in. East plant, slight infection on 1 branch, 3 healthy shoots; growth 2 in.	Disease has spread to entire plants, growth ½ in.

TABLE VI—Continued

Observations on 25 Field Pea Plants on the Ranch of W. F. Uray,
Center, Colorado, June 12 to June 24, 1915

Plant No.	Date of Observation:		
	June 12, 1915.	June 17, 1915.	June 24, 1915.
20.	Just showing disease below first branch.	One entire shoot dead and 1 healthy; growth 2 in.	No growth on old shoots; new shoots growing rapidly, 6 in.
21.	Slight infection at base.	One shoot frosted, 1 shows trace of disease at 2nd internode, and 1 infected at growing tip. Second shoot has grown 2 in.	Growth 1½ in. Plants same.
22.	White vine diseased at base; red vine normal.	Disease up to 3d node on white vine, and side branch involved. Red vine normal.	Disease to 5th node on white vine, growth 6 in. Red vine growing, 6 in.
23.	Disease beginning to show on lower leaves.	Three shoots: 1 dead, 1 diseased to 5th node, and 1 healthy.	Diseased branch has grown 1 in.; healthy shoot, 4 in.
24.	Normal.	Leaf infections common and 1 shoot affected to the 8th node. Normal stem has grown 2-¾ in.	Little change, practically no growth on infected stems.
25.	Normal.	Three shoots: 1 dead, 1 diseased, over 4 internodes, and 1 normal.	Diseased shoot has grown 4 inches; normal, 6 in.

Observations, July 1, 1915

Mr. Thomas visited this field on July 1 and found all remaining plants making good growth. The vines were badly matted around the stakes so that it was impossible to identify the particular shoots observed before. There was some evidence of whole plants having been killed, but in the majority of cases, new shoots replaced badly infected ones while stems with the disease on lower leaves and internodes either branched below the infection, or, in many cases, continued to grow in advance of the disease.

In connection with extensive variety tests which Mr. Thomas was conducting on field peas for forage purposes at La Jara, we have had an excellent opportunity to observe disease resistance to the bacterial blight. Out of the 48 varieties which we examined, there were 8 desirable varieties from a forage standpoint that showed any appreciable degree of resistance. Almost without exception, the best forage peas were the worst affected by the disease. The results of our observations on disease resistance are given in Table VII. The peas were planted May 3, 1915, and observed June 17, 1915.

Brief descriptions of the forage qualities of the different peas follow :

OBSERVATIONS MADE AT LA JARA, COLORADO, AT TIME OF
HARVEST, BY E. H. THOMAS, COUNTY AGENT

All varieties planted under same conditions and at same time; four fifty-foot rows of each. Planted May 3, 1915. Seed furnished by Bureau of Forage Crop Investigations and by experiment stations of Idaho, Washington, Oregon, Minnesota and Ontario. Some varieties were also furnished by the W. A. Davis Seed Company, and the Allen Seed Company. Some seed was purchased from points in the north and west.

NO. 11087.—EUGENE.—Produced slender short vine at La Jara. Yield of forage fairly heavy, with many well-filled pods. Should be excellent pea seed for heavy land, fairly early maturing.

NO. 16130.—GOLDEN VINE.—Produced a tall, medium-sized vine; fairly good quantity of forage, but with few pods and they were poorly matured. Might make good if planted early in light soil.

NO. 16436.—GREY WINTER.—Produced medium length, small-sized vine. Produced good quantity forage. Was extremely well podded but rather immature. Believe that peas should be sown probably on heavy or medium heavy soil late in fall or very early spring.

NO. 18455.—SHANGHAI.—Produced medium length, slender vine. Yielded fair amount of forage. Many medium-sized pods containing rather hard, medium-sized peas which shatter rather easily. Would no doubt make good forage or grazing pea on fairly strong land. Medium late.

NO. 19788.—POTTER.—Produced long coarse vine. Good amount forage. Yielded fair number pods, but poorly matured. Would probably make excellent forage pea on medium or heavy soil. Should be sown very early in spring.

NO. 20467.—SOLO.—Grown on medium, heavy land, produced long, medium-sized vine, yielding very good quantity of forage. Vine is extremely well podded thruout entire length; peas are rather soft. This variety should be excellent forage pea on heavy land and seed on lighter soils.

NO. 21288.—BANGALIA.—Slender, short vine, produced rather moderate quantity of forage when grown on medium, heavy soil. Produced a great many small-sized pods; rather early, drouth-resisting, should be great seed producer on heavy soils (or medium). Land should be fairly clean.

NO. 21289.—DESI.—Great number small, well-filled pods on short vine. Yield of forage light. Should make great grain production on heavy or medium heavy soils. *Do not* shatter easily.

NO. 21290.—KABILYA.—Produces medium vine. Good amount forage. Many pods. Excellent forage pea for heavy land; probably good seed pea on lighter soils. Should be planted early in spring.

NO. 21709.—AMORITI.—Medium length small-sized vine; fair yield forage. Many pods. Should be good pea for all classes of land. Seed and forage for heavy soils, also for medium heavy, and seed for light soils. Matures in good season, but should be planted rather early.

NO. 22007.—ALEXANDER.—Only medium yield of vine and seed. Does not seem to be anything extraordinary. Not enough pods for heavy land, nor enough vine for light land. Only fairly good yielder.

NO. 22036.—AGNES.—Long, coarse vine; fairly heavy amount of forage, but does not produce many pods, and is very late, should be planted very early in spring. Might make good forage pea for light land.

NO. 22037.—ARCHER.—Has long, coarse vine, good yield of forage, fair number of pods. More seed than 22036, but nothing extra; might make good forage pea on lighter soils.

NO. 22041.—GREGORY.—Same general type as 22037, but with fewer pods. Rank vine. Might make good forage pea for light soils. Should be planted very *early*.

NO. 22044.—PARAGON 12. Long, medium-sized stem; heavy yield of forage; medium number of pods. Might be good pea on lighter soils. Should be planted *very* early.

NO. 22078.—KILLARNEY.—Rather long, coarse stem, producing good quantity of forage. This variety is extremely well podded, compares rather favorably with 22043—Nelson. Should

be sown on light land for grain and early on medium or heavy land for either seed or forage. Might make good forage on light land.

NO. 22638.—CLAMART.—Vine tall or long and coarse; yields great quantity of forage. Produces very few pods. Would probably be good pea for lighter grades of soil. Should be planted early, so as to insure maturing of pods.

NO. 22639.—WHITE SCIMITAR.—Vines of medium length; slender stems. Yielding fair amount of forage. An excellent producer, a great many pods from $1\frac{1}{2}$ to 2 inches in length. Should be planted quite early, as this variety needs all the time possible to mature. A very good pea; would probably give best results from medium light land.

NO. 23290.—CHANG.—Medium length vine, coarse stem, yields good quantity forage. Many pods on upper or top half of vines, lower portion not so well podded. Would probably do better, pod more evenly if grown on light, sandy soil.

NO. 23848.—Vine long and fairly coarse. Fairly heavy yield of forage. Only moderate number of pods, but fair forage specimen; should be sown early.

NO. 23850.—LIMA.—Vines grow long and moderately coarse. Yields good amount of forage. Good many pods; very good pea, but should be planted early on light or medium light soils to secure best results for seed.

NO. 24314.—FRAILE.—Medium vine and stem; yields good quantity forage. Fairly well podded. Should be planted early to mature in good shape. Does not yield a great amount of either vine or grain.

NO. 25439.—OPENSHAW.—Vine of medium length, stem coarse. Good yield of forage. Great many pods. A good pea for almost any kind of land; forage and seed on heavy land, and seed on lighter grades. Plant fairly early.

NO. 25680.—BROWN ABYSSINIAN.—Medium vine and stem; fair yield of forage. Good yielder; many pods. *Does not* shatter easily. Should be good pea for harvesting; would grow in all grades of soil; earlier than all but a few varieties.

NO. 29368.—BLUE PRUSSIAN.—Vines medium, stems medium, yield of forage fair. Great many pods; would probably do well in clean, medium heavy land.

NO. 29371.—CHURCH.—Vines tall; medium stems; very good yield of forage. Many pods, very good pea. Would probably seed heavily on light soils. Should be planted rather early.

WHITE MARROWFAT.—Stems coarse, vines of medium length, yield of forage good. Great many good-sized pods. Should be planted early to insure maturing.

CHANCELLOR.—Medium vine and stem; good yield of forage: many well developed pods on vines. Good pea for heavier soils as well as excellent for seed on light soils.

TOM LEXINGTON.—Not much vine; yield of forage only fairly good. Quite a number of good-sized pods. A beautiful pea. Should be sown on good grade of clean ground.

MCKAY.—Very rank vine, yields much forage, very few pods. Would probably do better if planted early on higher lighter soil.

PROLIFIC.—Vines short; stem medium. Yield of forage rather light. A great many well-developed pods; peas are rather hard, might be grazed, as they shatter rather easily; would probably grow best on medium soil, but ought to be good peas on any clean ground.

ADVANCER.—Short slender vine, yield of forage rather light. Many fairly well-developed pods. Might do well on high medium heavy ground.

CARLTON.—Vines long and stem medium; fair yield of forage. Vine fairly well podded on upper position, lower 24 inches decayed at time of harvest. Might plant rather thin on higher land. Plant early.

ARTHUR SELDEN.—Vine very coarse and short. Good yield of forage. Good number fair-sized pods. Should be planted very early (when compared with early varieties).

PICKTON.—Vine rank and coarse, heavy yield forage. Good many fair-sized pods. Should plant early on light or medium soils.

EARLY FORAGE.—Short, sturdy vine. Pods mature even earlier than Horsford, and is heavier podded. Peas are soft, wrinkled and sweet; ought to be excellent for early grazing, yield of forage good, considering size of vine. Believe that this variety should be sown rather thick; should do well on heavy land.

TABLE VII

Disease Resistance—Variety Tests at La Jara, Colorado, Conducted by
Mr. E. H. Thomas. Season 1915—Observations made June 17, 1915

Variety No.	Variety Name.	Prevalence of Disease.	Quality as Forage Pea.
11097	Eugene	Bad	Good
16130	Golden Vine	Very bad	Very good
16436	Gray Winter	Bad	Poor
18455*	Shanghai	Slight	Good
19788	Potter	Bad	Poor
20467*	Solo	Slight	Good
21288	Bangalia	Bad	Very good
21289	Desi	Moderate	Poor
21290*	Kabilya	Very slight	Good
21709	Amoriti	Bad	Good
22007	Alexander	Very slight	Poor
22036	Agnes	Bad	Fair
22037	Archer	Moderate	Poor
22041	Gregory	Considerable	Poor
22044	Paragon 12	Moderate	Good but late
22078*	Killarney	Slight	Very good
22638	Clamart	Very bad	Poor
22639	White Scimitar	Very bad	Poor
23290*	Chang	Slight	Very good
23848	.....	Very bad	Good
23850	Lima	Slight	Fair
24314	Fraile	Very bad	Poor
25439	Openshaw	Very bad	Very good
25680	Br. Abyssinian	Slight	Fair
29368	Blue Prussian	Bad	Good
29371	Church	Bad	Good
	White Marrowfat	Considerable	Fair
	Chancellor	Moderate	Fair
	Tom Lexington	Very bad	Very good
	McKay	Bad	Good
	Prolific	Bad	Good
	Advancer	Very bad	Good
	Carlton	Bad	Poor
	Arthur Selden	Very bad	Very good
	Pickton	Bad	Fair
	Early Forage	Very bad	Very good
	Braden	Moderate	Good
	White Mexican	Very bad	Good
	Paragon	Very bad	Good, but late
	Late Forage	Bad	Very good
	Minn. 62	Bad	Good
26819	.....	Very bad	Very good
31073*	.....	Slight	Good
32003	.....	Very slight	Fair
32061	.....	Slight	Fair
32065*	.....	Very slight	Good
32104*	.....	Slight	Good
32123	.....	Very slight	Fair

The promising varieties are marked with an asterisk ().

METHOD OF INFECTION

Both our laboratory experiments and our field observations indicate that the causal organism enters the plants either thru the stomata or thru wounds produced by mechanical injuries.

In looking into the history of the trouble last spring we found one striking case where the outbreak unquestionably followed cultivation with a spike-toothed harrow at a time when the wind was carrying quantities of soil. The custom of harrowing to break the crust and to conserve moisture is a dangerous practice, because it wounds the tender plants and opens the way for soil infection. This was brought to our attention in a very graphic manner in a field where a large number of varieties had been planted for experimental purposes. A spike-toothed harrow had been dragged across the lower part of one of these rows and the upper end left untouched; all of the varieties blighted more or less in that portion of the row that was harrowed, while in the unharrowed part several of the same varieties exhibited marked resistance.

Two other instances were noted where infection followed closely upon a severe sand-storm which bruised the vines and literally injected the tissue with germ-laden soil particles. In fact, soil-laden wind alone, where it blows as violently and persistently as it does in Colorado in the springtime, is adequate explanation for all the infection that might ever occur in our State.

CONTROL MEASURES

1. Resistant varieties offer the only satisfactory remedy for the blight, and in the next two years we shall endeavor to obtain strains that are disease-resistant and, at the same time, desirable types both for forage and canning purposes.

2. In the meantime, when practicable, we would suggest planting from ten days to two weeks later than is the local custom.

3. So far as possible, avoid mechanical injury to the plants by harrowing or by other similar practices.

4. Avoid planting peas on the same land that was in peas the previous year, or where the disease has been present.

5. While we have had no opportunity as yet of determining whether the blight organism can pass thru the digestive tract of animals, fed with diseased vines, unharmed, and thus infect the manure, it may not be out of place to suggest the possibility of this at this time, and if we should have occasion to use any such manure on our gardens or in our fields, to remember that we may be sowing the seed of endless woe. Until we know definitely that

such fertilizer is free from this objection, its use should be regarded as a doubtful practice.

SUMMARY

1. The bacterial stem blight of field and garden peas occurs generally over the San Luis Valley and Northern Colorado, and to a limited extent in Nebraska, South Dakota and Utah.

2. It is characterized by the watery, olive-green to olive-brown color of the stems, and by the yellowish, bruised and watery-appearing stipules and leaflets.

3. A severe outbreak when the plants are young may reduce the stand one-third.

4. The blight is caused by *Pseudomonas pisi*, n. sp., which enters the tissue thru the stomata and thru wounds produced by mechanical injury.

5. Resistant varieties offer the only satisfactory remedy for the trouble, altho later planting may reduce the amount of the injury somewhat.

ACKNOWLEDGMENT

I am very greatly indebted to Professor B. O. Longyear for the preparation of the colored plate which appears in this bulletin, and to Mr. E. H. Thomas, of Alamosa, Colorado, for the many courtesies extended to me while studying the disease in the San Luis Valley, and for much of the field data presented herewith.

EXPLANATION OF PLATES.

PLATE ~~E~~. II

FIG. 1.—Pea leaf sprayed with a suspension of *Ps. pisi*, showing stomatal infection six days after inoculation.

FIG. 2.—Gelatin stab culture of *Ps. pisi*, kept at 20° C. and photographed after three days. Broad funnel-shaped liquefaction at surface, and slight growth along the line of the stab.

FIG. 3.—Gelatin stab culture of *Ps. pisi*, kept at 20° C. and photographed after eight days. Stratiform liquefaction at the surface, and slight growth along the line of the stab.

PLATE ~~H~~. I

FIG. 1.—Photomicrograph of *Ps. pisi* stained with carbol fuchsin, 24-hour agar culture. $\times 1000$.



PLATE I



1.



2.



3.



4.



5.

PLATE II



Fig. 1

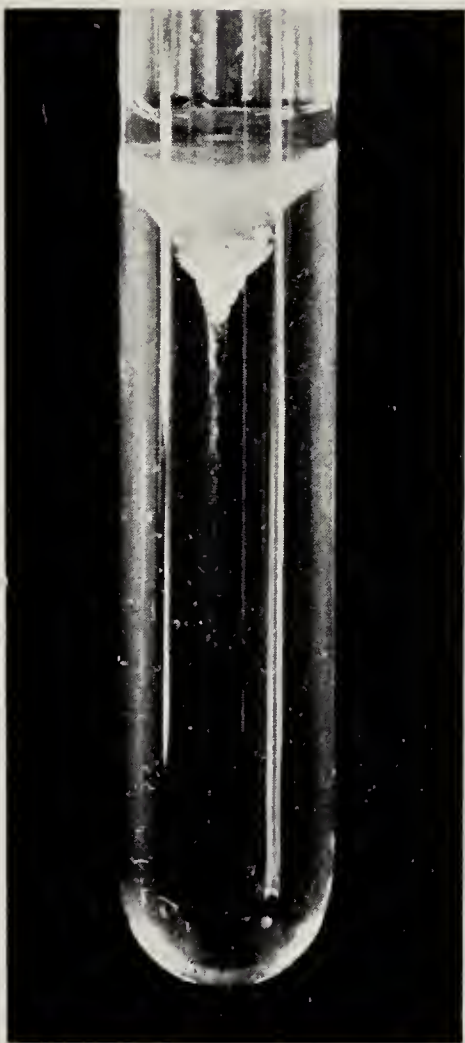


Fig. 2

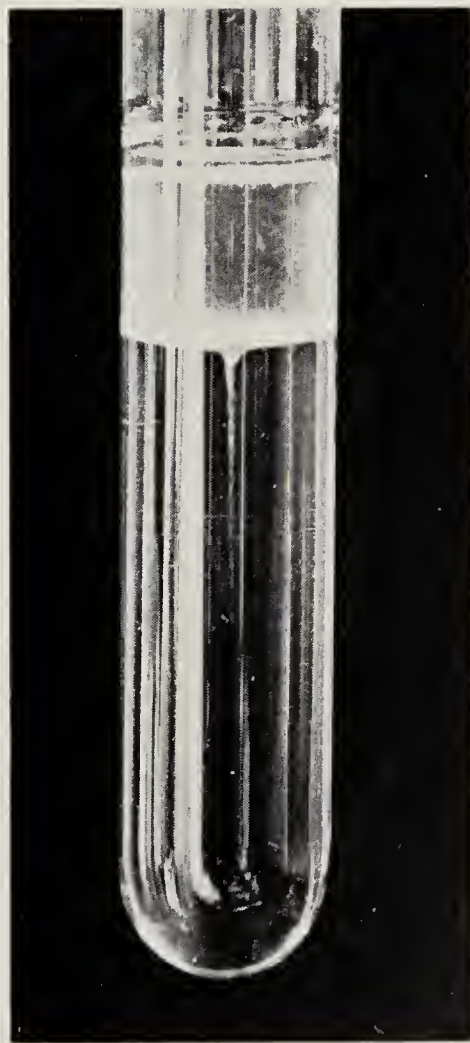


Fig. 3

FIG. 2.—Chains of *Ps. pisi* from 24-hour agar culture. Stained with carbol fuchsin. $\times 1000$.

FIG. 3.—Agar plate culture of *Ps. pisi*, showing surface and deep colonies. Five days old. Actual size.

FIG. 4.—Surface colony from agar plate. Five days old. $\times 100$.

FIG. 5.—Deep colonies of *Ps. pisi* from agar plate. Five days old. $\times 100$.

COLORED PLATE.

LEFT-HAND FIGURE.—Characteristic yellow, olive green, watery stipules and stem; recent infection.

MIDDLE FIGURE.—Diseased pea vine with olive green, watery stem and healthy shoot coming from below diseased portion. Infection active.

RIGHT-HAND FIGURE.—Pea vine in advanced stage of the disease.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART III

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A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART III

In the preceding portions of this work I have shown that the moisture which we determined at short intervals throughout the two seasons varied but little. These intervals were not all equal, but varied according to the weather or the application of water, irrigation. For the actual variation of this factor reference may be had to Bulletins 208 and 217. The moisture in the soil during the two seasons was not far from 15 percent. The plants did not, at any time, show the need of more water than was at their disposal.

The total nitrogen in the soil is given for a rather large number of samples of the surface soil, for the top four feet, and also for the top eleven feet. The surface portion varies considerably in the amount of total nitrogen present in it. The total nitrogen in 150 samples, taken at the same time and from a space 5 by 30 feet, varied from 0.11016 to 0.14552 percent. We have here a difference of 0.0354 percent of nitrogen. This variation involves an amount of nitrogen many times greater than that which, in the form of sodic nitrate, is necessary to produce most positive effects upon the growth and composition of the plant. The application of nitric nitrogen equivalent to 0.001 percent, or 10 parts per million is, in our case, sufficient to cause the grain to lodge, to change the physical properties of the kernels, also to increase the nitrogen in both the plant and kernel, and to affect the amounts of the various ash constituents appropriated.

THE FIXATION OF NITROGEN IN SOILS USED

In regard to the fixation of nitrogen by this soil, I have so far relied upon laboratory experiments, because the variation in the nitrogen content of field samples on a given date is greater than the amounts involved in the question of fixation itself. In the case just mentioned, we had a difference of 354 parts per million, and this difference was found on contiguous areas of 1 square foot each. The largest actual increase in the total nitrogen observed in this soil to which nothing but boiled distilled water had been added, was 105 parts per million; stated otherwise, samples gathered from the field on different dates cannot be relied on to either prove or disprove the fact

of fixation, for if the samples taken for this purpose at different dates had been taken on the same date, they would probably have varied in the same direction to such an extent as to render any conclusions based on them unsatisfactory, if not useless. It is not feasible to increase the number of subsamples sufficiently, in cases where one samples the land every fortnight, to eliminate this uncertainty.

If it be objected that the fixation found in a laboratory experiment lasting from 25 to 30 days is not a safe basis for estimating the extent to which this process may take place in the soil, the answer is evident. The results of the laboratory experiments prove conclusively, especially where the experiment is made with the soil without addition of anything except water enough to produce a favorable degree of moisture, 18 to 20 percent, that the soil is populated by an efficient nitrogen-fixing flora. While a laboratory experiment extending over 25 or 30 days does not prove that the fixation will proceed at the same rate for every other period of 25 or 30 days throughout the year, it does show that fixation is going on and may reach 105 parts per million, or 420 pounds of nitrogen for the surface acre foot, in one or more 30-day periods during the year. If we assume that the fixation is constant at one-half this rate, 50 parts per million, it would account for a large amount of nitrogen, the equivalent of a little more than 7 tons of proteid substance *per annum*.

For the benefit of some reader not accustomed to think in these terms, it may be stated that a fifty-bushel crop of wheat will correspond to about 4,500 pounds of straw. If the wheat weighs 62 pounds per bushel and carries 2.0 per cent nitrogen while the straw carries 0.3 percent nitrogen (this is a higher percentage than we have found in the stems and leaves taken together), the total nitrogen removed by the crop will amount to 74.0 pounds for each acre. If we assume the whole of this nitrogen to have been removed from the surface foot of soil, it is only three-fourths of the maximum fixation and one and one-half times the minimum obtained for a period of 30 days. The laboratory experiments have shown that it is possible for this soil to obtain from the atmosphere as much nitrogen in 45 or 50 days as the assumed crop of 50 bushels per acre would remove. This process tends to keep up the supply of nitrogen, but it is almost certainly not uniform throughout the year. We cannot judge of the amount of fixation by the variation in the amount of nitrogen present, for there is a considerable wastage of nitrogen from our soils. That such wastage takes place is common knowledge, still we may illustrate it by the results of a single irrigation made in 1913 by which we moved about 300 pounds of nitrogen per acre beyond the reach of any ordinary, cultivated plant. This is only one cause of wastage. The writer does not know the results obtained by other observers, but his own results indicate a discrepancy of upwards of 300 pounds per acre for which he can give no satisfactory accounting.

Realizing the weight of the misgivings that may be entertained regarding the applicability of laboratory results to this process of fixation, as it actually takes place in the field, which we have assumed in the preceding paragraphs, we have endeavored to meet them by taking 3,000 pounds of soil from the field, and determining the fixing power of this soil. The details of this experiment do not belong in this place but the general results are apropos to the question just raised.

The experiment was continued for 40 days under field conditions; the only departure from these that could possibly be urged against the experiment was that we endeavored to keep the moisture at uniformly 15.0 percent, it actually varied from this to 18.0 percent.

We found the maximum gain in total nitrogen during the fourth week of the experiment, when the average for the surface foot showed a gain of 45.5 p. p. m.

This period was followed by a rapid increase in the rate of nitrification. We have no check on the loss of nitric-nitrogen by its moving down to the bottom of our container and perhaps into the underlying soil. The important fact in this connection is that at the end of 40 days, this soil, to which nothing except ammonia-free distilled water had been added, showed a fixation of 36.0 p. p. m., calculated on the dry soil.

This experiment was performed under field conditions, not in an incubator nor in a laboratory, but with the soil taken from the wheat field and kept out of doors. It was protected so that animals could not have access to it, and so that no washings from neighboring soil in event of rain, could be carried down on it, and the immediately adjacent soil was wet down constantly to prevent blowing of foreign soil onto it.

We consider this conclusive proof that the laboratory results are applicable, and also that this soil fixes and nitrifies rapidly enough—we had an actual gain of 15.79 p. p. m. of nitric-nitrogen—to justify every claim made in this connection.

While I am persuaded that field samples can not be depended upon in the study of fixation, this is not the case with nitrification, for this nitrogen exists in a definite form which can be determined in its totality at any time with a very high degree of accuracy. That there is difficulty in obtaining representative samples does not need to be stated.

EFFECT OF WHEAT CROP ON FIXATION OF NITROGEN

We have followed the amounts of nitrates present in our soils for two years, and have shown that the amounts of nitrogen present in our soils in this form at different times vary greatly. After a thorough soaking of the land, or if the land is occupied by a good

stand of plants, the nitric-nitrogen present is naturally small in quantity, but under other conditions, it is always higher, and often quite high, though we are not now speaking of exceptional cases. On 4 August, 1915, we found, in the top four feet of a fallow plot, 47.4 pounds of nitrogen in the form of nitrates and 7.2 pounds in a like depth of soil planted to wheat. These quantities of nitric-nitrogen are equivalent to 284.4 and 43.2 pounds of sodic nitrate respectively. If this were a single or an exceptional instance, it would show only that this difference might exist in the amounts of nitric-nitrogen present in cropped and fallow land. This, however, is not an exceptional instance, every series of samples taken, 66 in all, shows the same fact. It is not held that the crop has used up this amount of nitrogen, but it is held that the crop either hindered the formation of nitrates or did exhaust them to this extent. The crop certainly did use up nitrates present in the soil, and also possibly hindered the formation of them. If the latter be true it was only a hindrance and not a destruction of the power of the soil to nitrify, for we have shown that the nitrates are rapidly replaced in this soil as soon as the crop is removed. The same plot that on 4 August, 1915, showed the presence of nitric nitrogen, equivalent to 43.2 pounds of sodic nitrate, showed, on 13 December, 1915, taken to the same depth, the equivalent of 232.7 pounds, or five times as much as on 4 August. Nothing had been added to this soil except the wheat stubble which had been disced into the surface soil. Irrigation was not necessary, as enough rain had fallen to keep the soil fairly moist. It is not probable that the wheat stubble disced in modified, in any essential way, the process of nitrification, for the increase of nitrates in the soil began immediately after the removal of the crop and before the stubble was disced in. There is no question about the action of more considerable quantities of decaying organic matter upon the processes of fixation and nitrification but in this case the quantity did not seem to be sufficient to produce observable results, or obscure in any way the process of nitrification, for our samples were not taken close enough together to establish the rate of nitrification from one week to another or to detect variations in this rate.

The quantities of nitrogen thus transformed into nitrates during a single season are more than sufficient to justify their consideration in connection with our problem. We found in the 2nd, 3rd and 4th foot of a sample of this soil taken 29 April, 1913, 23.8, 33.8 and 12.9 parts nitric-nitrogen per million, respectively. These quantities seem high, but we have found in fallow spots in this same land, cultivated to beets, 22, 28, and 35 parts nitric-nitrogen per million in the surface portions of the soil. When one bears in mind that the ratio of available potassium in the land is so high that its specific action on the character of the wheat produced is easily recognized in the plumpness and color of the kernels, and that the supply of available phosphorus

is such that the addition of considerable quantities of this element, up to 60 pounds of soluble phosphorus per acre, produces no perceptible effect upon the crop, it will be appreciated, that the formation of quantities of nitrates corresponding to the amounts of nitric-nitrogen given above, or even the less amounts indicated by our general samples, may produce a very pronounced influence upon the character and properties of the wheat produced.

In order to find out what effects we were to expect from the predominance of one or other of the three elements usually considered in this connection, nitrogen, phosphorus and potassium, but particularly of nitrogen, we applied these singly in different quantities, aiming to have a very excessive quantity in at least one case in each series of experiments. To these three elements of plant food we added water, because the supply of this is usually under our control in Colorado and our opportunity for studying its effects is better than that enjoyed by many other experimenters.

APPLICATION OF WATER A PHYSIOLOGICAL PROBLEM

I will digress to state what seems self evident, i.e., that the question of an advantageous or indispensable water supply to the wheat plant, for instance, is rather a physiological than an engineering question, though it is generally considered from the latter standpoint. It is not only a question of how much or little water is actually needed, but also a question of the time and manner of application. To be more specific, I believe that the application of one acre-foot of water at the proper time may produce just as favorable results as the same amount differently distributed in regard to time. Further, 1 foot, or even less, of water, applied at the proper time may produce just as good results as 2 or even 3 feet, provided that the supply at the proper time in the development of the plant be adequate to its needs; after this the water supplied is of little or no benefit, and produces but little or no effect upon the composition of the plant or grain. Two feet of water applied to the soil as irrigating water, even if it be distributed at intervals of a few days, eight to ten days, may do neither the plants nor the grain any harm, and produce no perceptible difference in the composition of either. Whereas, the same amount of water falling in a series of light rains would certainly prove detrimental, perhaps disastrous, even though the last ten, or possibly even fifteen days before harvest were fair and dry. A comparison of the composition of the plant, as indicated by the various forms of nitrogen and the ash constituents given for the crop of 1913, in Bulletin 208, with that for 1915 in Bulletin 217, in which years the plants received essentially the same amounts of water, will show how great a difference the manner of application may make. In 1913, the crop received 12 inches as irrigating water and 6.77 inches rainfall; in 1915, it received 13 inches of rainfall and 6 inches of irrigating water. The plants in 1915 contained less nitrogen and smaller

amounts of ash-constituents. The variety of wheat referred to was the same and grown on the same land with the same fertilization. Further, it is a matter of common knowledge that a very light rainfall or heavy fog, just before the ripening period, may cause injury both to the quantity and quality of the crop. If this were not already so well known, we would appeal to our experience in 1914, when a comparatively small amount of rainfall injured our Defiance plots to an extreme extent and all of the plots seriously. In this case rust produced severe injury to the crop, but especially to the Defiance. There were some effects which could not be attributed directly to this parasite, especially in the light of other experiences, but probably should be attributed directly to the wetting of the plants.

EFFECTS OF NITROGEN, PHOSPHORUS AND POTASSIUM

To return to our subject, we found that under our conditions nitrogen produces the most marked effects upon the growth and composition of the plants; that phosphorus and potassium produced less effect than other observers have recorded. For instance, phosphorus did not hasten, nor the nitrate delay, maturation as observed by others. This statement holds irrespective of the amounts applied. It is true that rust interfered two years out of three, particularly in the case of the Defiance.

In the case of the Defiance, all amounts of nitrates applied caused lodging, and that badly. It produced the same tendency in the Red Fife and Kubanka, but these varieties did not suffer much on this account; they did, however, show other effects of the nitrates, such as heavier, darker leaves, slightly taller plants and longer heads, but the average number of kernels to the spikelet was found to be slightly lower. The kernels were smaller, darker in color, flinty, and sometimes shrunken.

Phosphorus, on our plots, produced no perceptible effect upon the growth of the plant, the time of ripening, or the physical properties of the kernels.

The plants on the plots which had received dressings of nitrate and were planted to Red Fife or Kubanka differed so little from the others, that it was only by the darker green color of the plants that one could readily distinguish them. This was not the case with the Defiance, for in these plots the wheat which had been dressed with nitrate went down flat, showing sharply the last drill row to which the nitrate was applied.

Potassium showed at one period a slight hastening in the development of the plant, but this advantage was soon lost and plants grown on the check plots and on those that had received an application of phosphorus, attained the same height and the same perfection of de-

velopment, so that no difference in the plants grown on these plots could be perceived.

While there were but few, or almost no recognizable differences in the growth and ripening of the plants in comparison with the check plots, there were differences in the physical properties of the kernels. The kernels grown with the application of phosphorus, of potassium, and those on the check plots, were plump and of good size, while those grown with the application of nitrate, were smaller and somewhat shrunken. The chief physical characteristics were shown by the wheats grown with the addition of potassium and these were most pronounced in the Kubanka. These wheats show a difference in their general appearance, in the brightness of the kernel, and especially in the presence of mealy or half-mealy kernels. Yellow-berry was more prevalent than in wheats from the other plots, i.e., than in either those from the check plots or such as had been grown with the application of phosphorus. There are no decided differences between the physical appearances of wheats grown on check plots and those grown with the application of phosphorus. This is not the case with wheat grown with the addition of nitrogen; such wheats are, as has already been stated, small grained or even shrunken, dark colored, and flinty. The starchy or mealy berries are either greatly lessened in number or are absent.

So far, we have stated the physical differences shown by the plants and also the kernels. Bulletin 205 deals with the physical properties of the kernels, while Bulletins 208 and 217 deal with the soil, the chemical composition of the plants, and some other factors. There we find that these fertilizers exert specific influences which are not apparent in the physical appearance of the plants. The greatest correspondence between the physical appearance and chemical effects is found in the case of nitrogen, which produces in the plant an appearance of luxuriance. We find that it increases the nitrogen content of the plant, and modifies the amount and percentage composition of the ash. Further, these elements, nitrogen, phosphorus, and potassium, mutually influence the intake of one another; for instance, nitrogen, applied in liberal quantities, increases the amount of potassium appropriated by the plant. As I have applied only sodic nitrate as a source of nitrogen, it is possible that this effect may be attributed to the action of the sodium upon the soil. Be this as it may, the amount of potassium appropriated was increased, also the amounts of lime and magnesium, while the amount of phosphorus appropriated by the plant or found in its ash was not influenced. The succulency of the plant was increased, or, put the other way, the amount of dry matter in the plant was decreased. Phosphorus did not appear to exercise any marked influence upon the nitrogen content of the plant; potassium lowered it. Bulletins 208 and 217 treat of these features more fully.

PURPOSE OF THIS PART OF OUR STUDY

In this part of our study we propose to present the composition of Colorado wheats in general, in so far as it seems to have any purpose, and then to present the results of our study of the effects of these fertilizers, of water, and in some measure, of the weather, upon the composition of wheat. We will leave the question of the milling and baking qualities for future consideration.

The only person, who, to my knowledge, has treated in any way of the composition of Colorado wheats, is Mr. Clifford Richardson, who apparently analyzed samples of wheat grown at this station by Prof. Blount. Mr. Richardson's conclusions are favorable to Colorado as a producer of wheat of high quality. A few quotations from his report are interesting, even if subsequent developments make us wish that the properties of our wheats might measure up more fully to his estimates of them. He says: "Among the individual states, Colorado sustains the reputation gained in last year's report of producing the finest wheat. . . . Minnesota, all things considered, probably ranks next to Colorado."* "As has been seen, the Colorado wheats are certainly the best which have been produced in this country. For two years they have sustained a high average composition and a large weight per 100 grains. Why do they excel in this manner? It is due somewhat to careful cultivation and selection of seed, but more largely to soil and climate as is proved by the experiments of last year."

Of thirteen varieties grown by the department and at the Colorado Experiment Station from the same lots of seed Mr. Richardson says: "In every case the size and general appearance was much improved and, as a consequence, the weight of 100 grains of the crop was much heavier than the seed; in fact, averaged over 26 percent heavier."

"Of 44 wheats from Colorado, grown during two years, only one fell below 11.5 percent of albumin and only six below 12 percent."

"Too much confidence, it is seen, cannot be placed on the size and appearance of a wheat or conversely on the chemical analysis alone. When both these elements in its constitution are favorable, then alone can it be pronounced a good wheat."

"The effects upon the composition of grain which we have studied seems to be largely dependent upon the soil, seed and cultivation being the same."†

Dr. H. W. Wiley, in discussing Mr. Richardson's conclusion, says: "Mr. Richardson was of the opinion, as a result of these studies, that the soil was the most important factor in producing these varieties. A subsequent study of the department, which will be referred to later on

* Report U. S. Dept. of Agri., 1883, p. 210.

† Report of U. S. Department of Agri., 1883, p. 211.

seems to show that, in this respect, he was mistaken, and that the soil, as a rule, has the least effect of all the important factors of environment upon chemical composition, provided, of course, that it contains the essential elements of plant food necessary to produce an average crop. The soil, it is true, is one of the most potent factors in determining the size of the crop and the amount of material which is harvested, but it does not have a very marked influence on the chemical composition of the crop produced.”*

Dr. Wiley does not call Mr. Richardson's facts into question, only his explanation of them. Mr. Richardson attributes the characters of the wheat to the properties of the soil. Dr. Wiley says that the soil has the least effect of all the important factors of environment upon chemical composition, provided it contains the essential elements of plant food, necessary to produce an average crop.

I know nothing about the views that Mr. Richardson may have adopted subsequently, but these quotations present the question in regard to the part played by the soil and the other environmental conditions as succinctly as any others that I might quote. I think that the greater number of writers on this subject agree in their general attitude with the position indicated by the quotation from Dr. Wiley, which, perhaps, is not so decided as the statements of some others. Dr. J. A. Le Clerc says: “The results so far obtained would seem to indicate that the soil and seed play a relatively small part in influencing the composition of crops.”† This is one of the conclusions from their tri-local experiments with wheats.

Schindler, in discussing a wheat climate, says: “We shall have to remind the reader that the climate of the Colorado section is characterized by an extraordinary dryness of the atmosphere and great daily variations of temperature. The relative humidity falls as low as 10 per cent.” Then he quotes Hann, *Climatology*, p. 662: “The advantages of the Colorado climate consist in the clearness of the sky, intense sunshine, and a light atmosphere favorable to evaporation.”§

Dr. Le Clerc says, in writing of irrigation: “Where irrigation is practiced, in Colorado for example, ideal conditions for plant growth prevail, for there the sky is clear, the sunshine intense, the air dry. Therefore, if water can be supplied when the crops are in need of it, assimilation will go on at its best and the production of organic substance will be all the more favored. The result will be a large crop of large-sized grain.”‡

No author, whose writings I have read, is more insistent upon the very great influence of “climatic conditions” than Schindler, who sets forth strong reasons for his views. Still he acknowledges that soil conditions may produce similar effects. In discussing correlative

* Year Book of the Dept. of Agri., 1901, p. 303.

† Bureau of Chemistry, U. S. Dept. of Agri., Bul. 128, p. 185.

§ Translations by the author.

‡ Year Book U. S. Department of Agriculture, 1906, p. 204.

variability he says: "The study of the wheat plant in regard to its correlative variability has lead to the conclusion that this can be called into activity, not only by transference to another climate, but also by other extraneous conditions, though climate exercises the greatest influence upon its persistency (Dauer). A change in the character of the soil, be it by change of locality, by manuring, or by cultivation, has a similar action in that the conditions of nutrition are changed and with these the organic efficiency" (of the plant) **

Though Schindler in this way recognized the influence of the soil, still, he scarcely mentions it in the first half of his work, but attributes the greatest influence in determining the character of wheat to the climate. This is, in fact, his thesis.

A paragraph of his relative to Colorado is of sufficient interest to justify its reproduction. After quoting some analyses of Colorado wheats he continues: "I have referred previously to the fact that the cultivation of wheat in this zone (the western plateau and mountain region of the United States) is only possible under irrigation, but which, under the other favorable climatic conditions, yields extraordinary results, as it can be applied at exactly the opportune time. The high yield and weight per kernel is explicable only by this. The relatively high protein content is noteworthy, and is probably dependent upon the characteristics of the soil, which is reputed to be very fertile. The Blount samples excel in this point and suggest that their richness in protein has been forced up by a corresponding application of manure, which is, as is known, easily done. Blount rightly praises the action of sheep manure upon his crops. This was, without doubt, the lever to which he owed his striking results and not his crosses whose influences are difficult to control."†

If the soil has so little to do with the composition and quality of the crops, our wheat ought to be both uniform and good, for our climate is favorable and we have the water supply largely in our control. I think that this statement is true, though the State is large, varies in altitude from 3,000 to 7,500 or even 7,700 feet in the districts where wheat is successfully cultivated, and also in climate. I know of no section, however, of high rainfall. The average annual rainfall at Fort Collins is 14.9 inches and at Grand Junction it is about one-half as much.

I have already stated in Part I of this study that, according to the best information that I can obtain, flour made from Colorado wheat

* Schindler, *Der Weizen in seiner Beziehung zum Klima und das Geset der Correlation*, 1883, p. 138. Translation by the author.

† Schindler, *Der Weizen*, p. 72. Translation by the author.

falls from 30 to 40 loaves per barrel behind Kansas and the best Minnesota flours.

This seems to be contradictory to what we should expect, as our summers are usually dry and the days hot. Our spring wheat matures in from 100 to 128 days from planting.

We shall present in the following pages the analytical results obtained in the study of the wheats grown in the seasons of 1913, 1914, and 1915.

The varieties grown were Defiance—a wheat originated at this station by the late Prof. A. E. Blount—Red Fife, and Kubanka. The seed of the last two varieties was obtained from the South Dakota Experiment Station.

The three seasons were very different, and the data pertaining to temperature and rainfall do not convey a very definite idea of the weather conditions that prevailed; nevertheless, I shall give them as furnished to me by Mr. R. E. Trimble, who is in charge of such observations

1913	April	May	June	July	August
Mean Air Temperature.....	46.1	54.8	63.2	66.8	69.8
Mean Soil Tem. 3".....	46.2	58.7	67.9	71.7	74.4
Mean Soil Tem. 6".....	46.3	58.8	67.9	72.6	75.2
Rainfall (inches)	1.49	2.09	0.15	2.63	0.41
Cloudy or partly cloudy days.....	17	21	19	18	11
1914	April	May	June	July	August
Mean Temperature of Air.....	44.75	54.56	63.58	68.30	66.95
Rainfall inches	3.23	2.73	2.01	1.68	1.28
1915	April	May	June	July	August
Mean Temperature of Air.....	50.04	50.35	59.62	64.74	62.77
Temperature of soil 3 inches A. M.....	45.25	48.96	58.03	63.30	61.00
P. M.....	54.62	59.66	69.58	75.10	72.00
Rainfall (inches)	4.01	3.78	1.90	2.12	1.56
Cloudy or partly cloudy days.....	19	21	15	19	21

This tabulation gives a record of the rainfall, for instance, as accurately as we can read the pluviometers, or the temperature, as accurately as we can read the thermometers, but it does not give us the deciding factors in the development of the wheat. The rainfall up to 12 June in any of the three years was probably without influence upon our crop, as there was at no time a lack of moisture up to this date. On 12 and 13 June, we applied 1 acre-foot of water. This much was necessary, especially in 1913, for with less water we could not get over the ground. A few spots which were not covered, owing to the imperfect leveling, produced only a very light crop of grain. The rainfall in July, 1914, was only 1.68 inches, but 1.45 inches of it fell during a very few days late in the month and a very good portion of this came in one violent shower, about fourteen days before harvest. This

rain did apparently but little injury to two of the varieties, but injured the third, especially those plots which had been treated with sodic nitrate, very badly. This rainy period was, of course, accompanied by more or less cloudiness and dewy nights. I have given the number of cloudy days for the months concerned in 1913 and 1915. This simply gives a general and very indefinite measure of the sunshine. These tables, however, give the best meteorological data that I have.

The crops for the three seasons are given in the following tabular statement. The bushels are thresher weights; the weight per bushel is for cleaned wheat; and the ratio of straw to wheat is based upon the weights of straw and grain as threshed.

CROP OF 1913

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	34.83	61.00	1.34
1800	Defiance	Nitrogen 80	38.83	60.00	1.17
1900	Defiance	Nitrogen 40	29.00	61.50	1.33
1700	Defiance	Phosphorus 60	28.30	62.00	1.14
1800	Defiance	Phosphorus 40	39.50	62.00	1.29
1900	Defiance	Phosphorus 20	33.83	62.50	1.41
1700	Defiance	Potassium 200	38.50	62.00	1.16
1800	Defiance	Potassium 150	41.66	62.00	1.32
1900	Defiance	Potassium 100	33.00	63.00	1.29
1700	Defiance	Check	41.41	62.00	1.45
1800	Defiance	Check	40.58	62.50	1.57
1900	Defiance	Check	41.33	62.50	1.54
1700	Red Fife	Nitrogen 120	37.08	62.75	1.62
1800	Red Fife	Nitrogen 80	39.91	63.00	1.75
1900	Red Fife	Nitrogen 40	33.81	64.00	1.90
1700	Red Fife	Phosphorus 60	27.83	63.25	1.32
1800	Red Fife	Phosphorus 40	34.00	63.50	1.62
1900	Red Fife	Phosphorus 20	31.29	64.25	1.34
1700	Red Fife	Potassium 200	31.27	63.50	1.35
1800	Red Fife	Potassium 150	33.91	63.50	1.53
1900	Red Fife	Potassium 100	32.83	64.25	1.64
1700	Red Fife	Check	33.16		1.79
1800	Red Fife	Check	32.75	63.50	1.55
1900	Red Fife	Check	33.91	64.50	1.54
1700	Kubanka	Nitrogen 120	41.41	62.75	1.49
1800	Kubanka	Nitrogen 80	39.82	63.00	1.68
1900	Kubanka	Nitrogen 40	39.00	64.00	1.57
1700	Kubanka	Phosphorus 60	32.80	64.50	1.28
1800	Kubanka	Phosphorus 42	39.60	64.50	1.40
1900	Kubanka	Phosphorus 20	32.40	64.25	1.57
1700	Kubanka	Potassium 200	33.80	64.25	1.31
1800	Kubanka	Potassium 150	36.08	64.75	1.51
1900	Kubanka	Potassium 100	30.50	64.50	1.35
1700	Kubanka	Check	34.00	62.50	1.35
1800	Kubanka	Check	34.16	63.50	1.39
1900	Kubanka	Check	34.33	63.50	1.67

CROP OF 1914

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	25.70	52.00	2.73
1800	Defiance	Nitrogen 80	26.70	56.00	2.53
1900	Defiance	Nitrogen 40	28.50	54.25	2.48
1700	Defiance	Phosphorus 60	33.33	58.00	1.55
1800	Defiance	Phosphorus 40	34.50	58.50	1.64
1900	Defiance	Phosphorus 20	34.00	56.50	1.62
1700	Defiance	Potassium 200	39.16	60.00	1.48
1800	Defiance	Potassium 150	34.33	59.50	1.52
1900	Defiance	Potassium 100	33.33	59.50	1.77
1700	Defiance	Check	32.83	58.25	1.97
1800	Defiance	Check	30.60	56.00	1.99
1900	Defiance	Check	30.00	56.00	1.92
1700	Red Fife	Nitrogen 120	55.50	64.50	1.48
1800	Red Fife	Nitrogen 80	53.00	64.25	1.64
1900	Red Fife	Nitrogen 40	52.33	64.00	1.66
1700	Red Fife	Phosphorus 60	49.33	63.50	1.33
1800	Red Fife	Phosphorus 40	47.66	63.50	1.78
1900	Red Fife	Phosphorus 20	49.33	64.00	1.54
1700	Red Fife	Potassium 200	44.83	63.00	1.54
1800	Red Fife	Potassium 150	45.33	64.25	1.54
1900	Red Fife	Potassium 100	50.33	63.75	1.60
1700	Red Fife	Check	48.60	63.50	1.64
1800	Red Fife	Check	45.70	63.75	1.54
1900	Red Fife	Check	47.33	63.50	1.57
1700	Kubanka	Nitrogen 120	51.66	65.00	....
1800	Kubanka	Nitrogen 80	52.66	64.50	1.53
1900	Kubanka	Nitrogen 40	51.16	64.50	1.53
1700	Kubanka	Phosphorus 60	54.50	64.50	1.37
1800	Kubanka	Phosphorus 40	51.00	65.00	1.44
1900	Kubanka	Phosphorus 20	48.33	65.50	....
1700	Kubanka	Potassium 200	51.16	65.00	1.33
1800	Kubanka	Potassium 150	49.16	65.00	1.49
1900	Kubanka	Potassium 100	43.00	64.50	1.60
1700	Kubanka	Check	52.83	64.75	1.21
1800	Kubanka	Check	46.66	65.00	1.33
1900	Kubanka	Check	44.00	65.00	1.90

CROP OF 1915

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	8.33	47.00	13.40
1800	Defiance	Nitrogen 80	10.83	47.00	7.00
1900	Defiance	Nitrogen 40	13.70	51.00	4.50
1700	Defiance	Phosphorus 60	21.16	51.00	3.19
1800	Defiance	Phosphorus 40	22.50	50.00	3.96
1900	Defiance	Phosphorus 20	30.40	52.75	2.54
1700	Defiance	Potassium 60	26.83	53.00	3.16
1800	Defiance	Potassium 40	25.33	52.50	2.13
1900	Defiance	Potassium 20	23.50	55.25	3.33
1700	Defiance	Check	20.58	49.75	3.05
1800	Defiance	Check	19.50	49.00	4.43
1900	Defiance	Check	18.50	50.00	2.84
1700	Red Fife	Nitrogen 120	23.33	53.50	3.79
1800	Red Fife	Nitrogen 80	23.66	56.50	4.69
1900	Red Fife	Nitrogen 40	24.50	56.25	3.12
1700	Red Fife	Phosphorus 60	31.33	60.00	3.17
1800	Red Fife	Phosphorus 40	33.00	60.00	2.43
1900	Red Fife	Phosphorus 20	29.50	61.00	3.28
1700	Red Fife	Potassium 200	32.50	61.50	2.28
1800	Red Fife	Potassium 150	33.16	60.25	2.84
1900	Red Fife	Potassium 100	30.83	60.00	2.22
1700	Red Fife	Check	32.33	60.75	3.12
1800	Red Fife	Check	33.61	60.50	2.36
1900	Red Fife	Check	31.00	61.00	3.15
1700	Kubanka	Nitrogen 120	35.50	59.00	2.90
1800	Kubanka	Nitrogen 80	40.83	60.00	2.09
1900	Kubanka	Nitrogen 40	21.91	61.00	2.09
1700	Kubanka	Phosphorus 60	36.50	62.50	2.06
1800	Kubanka	Phosphorus 40	39.75	62.25	2.36
1900	Kubanka	Phosphorus 20	23.75	62.00	2.44
1700	Kubanka	Potassium 200	36.16	62.75	2.55
1800	Kubanka	Potassium 150	34.91	63.00	2.70
1900	Kubanka	Potassium 100	25.01	62.50	3.64
1700	Kubanka	Check	36.25	62.00	2.68
1800	Kubanka	Check	35.16	63.00	3.10
1900	Kubanka	Check	27.00	63.00	2.55

It is scarcely proper to give the ratio of straw to wheat for 1915, for the reason that a very liberal seeding of wild oats was applied with the irrigating water in September, 1914, preparatory to cultivation. There was enough of the wild oats to affect the ratio so seriously as to make it of but little value, still it does not lead us astray in concluding that the ratio in 1915 was not far from twice as high as in the preceding years. The promise for a very large yield was good up to the last week in July, except on the nitrated plots, some of which were badly lodged. About the end of July, due to light rains and cloudy weather, rust attacked all of the plants badly, but injured the Defiance worse than the other varieties. It is my judgment that the effects of this parasite, which were marked, upon the composition of the plant, as is shown in Bulletin 217, were greater than those of the weather.

An inspection of these data shows some interesting things, especially when taken in connection with the weather conditions. Our table on a previous page shows that we had a rainfall of 2.63 inches during July of 1913, 0.8 of an inch fell on the 18th, and 1.19 inches on the 23rd, which was cloudy all day, otherwise the sky was practically clear during the month and also during August. The yield of the Defiance was a trifle better than that of the other varieties. Its weight per bushel being between 60 and 63 pounds, and the maximum ratio of straw to grain was 1.57. It was surpassed in weight per bushel, but in no other respect by the other varieties. In 1914 we had an excellent season, with only 1.68 inches of rainfall in July. We had a shower on 30 July, during which, 0.87 of an inch of rain fell. This shower was violent and beat down the grain somewhat, especially the Defiance, which was luxuriant and growing rapidly. Rust developed and the grain ripened prematurely. The minimum yield of Defiance fell almost 30 bushels per acre below the maximum for the Fife. Only one plot in the twelve yielded grain weighing 60 pounds per bushel and one plot yielded grain weighing only 52 pounds, while the minimum for the other two varieties was 63 and the maximum 65.5 pounds per bushel. The maximum yield of Defiance was 39.16 and the minimum 25.70 bushels. The maximum yield of the other two varieties was 55.5 and the minimum 43.00 bushels per acre.

The Red Fife and the Kubanka are a little earlier and, perhaps, a little more resistant to rust than the Defiance. These seem to have been the determining factors in this year's crops. In 1915 we did not have so much rain in July as in 1913 but the two seasons were quite different; 1915 was much more cloudy; we had a succession of light rains and the dews were heavy. Rust was bad on all varieties and the Defiance was practically a failure. The biggest yield was 26.8 bushels, weight 53 pounds, the minimum 8.33 bushels, weight 47 pounds. The Red Fife grown with the application of sodic nitrate rusted very badly and yielded only about 24 bushels, weighing 56 pounds to the bushel. Most of the other plots yielded from 30 to 40 bushels, weighing from 60 to 63 pounds per bushel.

THE FACTORS WHICH DETERMINED OUR CROPS

The factors which determined our crops were evidently not the quantity of rainfall but its distribution, the degree of cloudiness, the resistance of the plant to rust, its stage of development when this attack came, the temperature, and the fertility of the soil. The plants grown with the application of nitrates were attacked more severely by

rust than the others. Whether this was due to the stage of development or to the characters of the tissues may be a question. We have not been able to detect any difference in the date of the ripening of the grain due to the nitrate on the one hand or the phosphate on the other, so the question of development does not press itself very strongly as accounting for the greater degree in which the nitrate plants were infested. There is an abnormal ripening in the case of plants grown with the application of nitrates, in that the leaves and middle parts of the plants ripen more slowly than the top and bottom, but we have found no difference in the ripening of the grain.

While these cultural results are of great importance in determining the character of the material with which we have to deal, and, unfortunately, complicate our question, they are, after all, incidental, even though their consideration cannot wholly be set aside.

THE CHARACTERISTICS OF COLORADO WHEAT

The first subject that we shall try to consider in regard to Colorado wheat is, whether the composition of the wheat shows anything characteristic.

The wheat grown in the State, even at the present time, is largely spring-wheat, though winter-wheat is being grown in larger quantity than formerly. For this reason I shall present analyses of both spring and winter-wheats. In regard to the samples sent to me from different localities, I can give no details, other than the names and localities furnished me. This pertains only to some of the general samples. These analyses appear on the pages immediately following.

GENERAL SAMPLES OF SPRING WHEATS—CROPS 1912 AND 1913

	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Defiance, Ft. Collins, Seed, used.....	9.920	1.793	1.818	2.710	2.361	13.458	61.468	1.375	30.66	11.74	8.504	.....	.....
Defiance, La Jara, Yellow-berry, 1912 very bad	10.615	1.686	1.863	2.725	1.454	8.288	64.134	1.409	14.03	6.10	4.221	0.394	0.423
Defiance, Del Norte, Yellow-berry.....	10.655	1.915	1.835	2.423	1.413	8.054	64.890	1.386	13.73	5.44	4.001	0.434	0.526
Defiance, Ft. Collins, not irr. 1913.....	11.683	1.680	1.698	2.600	2.444	13.932	62.118	1.046	35.33	13.41	9.707	0.336	0.343
Defiance, Grand Junction, 1912.....	9.063	1.500	1.670	2.492	2.442	13.917	62.964	0.924	29.73	10.90	8.430	0.271	0.431
Defiance, Clifton, 1912.....	9.338	1.782	1.855	2.312	2.533	14.440	62.520	1.415	28.47	11.68	8.225	0.329	0.400
Defiance, Ft. Collins, 1911.....	9.355	1.774	1.588	2.425	2.618	14.923	60.264	1.096	23.30	12.89	9.723	0.376	0.414
Sonora, Del Norte, 1912.....	10.533	1.731	1.850	2.515	1.974	11.251	63.666	1.561	21.47	8.71	6.082	0.399	0.403
Kubanka, Limon, dry land, 1912 (starchy)....	10.235	2.091	1.893	2.455	2.278	12.985	59.490	1.513	30.00	12.49	9.120	0.363	0.440
Kubanka, Ft. Collins, 1912 (starchy).....	.....	.....	.....	.....	1.847	10.527	.....	.....	.....	.....	.....	.....	.....
Kubanka, Ft. Collins, 1912 (flinty).....	11.200	1.917	1.835	2.525	2.240	12.768	62.046	1.467	25.40	10.79	7.661	.....	.....
Red Fife, Ft. Collins, not irr., 1913.....	10.495	1.507	1.933	2.523	2.667	15.204	61.686	1.006	38.00	14.83	10.900	0.293	0.357
Red Fife, Ft. Collins, fallowed, 1913.....	9.138	1.929	1.770	2.620	3.008	17.143	59.076	1.153	40.67	15.58	11.594	0.414	0.380
Marquis, Ft. Collins, fallowed, 1913.....	9.108	1.861	1.988	2.525	2.807	15.998	59.886	1.266	38.63	15.06	11.042	0.402	0.409
Minn., Spring No. 1, Minneapolis, 1912.....	8.395	1.923	2.113	2.820	2.248	12.811	63.288	1.215	24.67	9.88	7.524	0.418	0.459
Minn., Spring No. 2, Minneapolis, 1912.....	8.378	1.819	2.033	2.835	2.212	12.610	62.066	1.175	26.27	10.29	7.843	0.381	0.458
Minn., Spring No. 3, Minneapolis, 1912.....	8.235	1.823	1.963	2.750	2.139	12.193	63.648	1.278	24.73	9.62	7.182	0.398	0.452
Red Fife, So. Dak. Expt. Sta. Seed used, 1912..	10.606	1.749	1.830	2.400	2.249	12.821	59.814	1.215	29.33	11.32	8.225	0.279	0.490
Red Fife, So. Dak. Expt. Sta. Crop, 1913.....	8.908	1.879	1.860	2.675	2.327	13.265	62.280	1.289	28.43	11.41	8.550	0.321	0.420
Kubanka, So. Dak. Expt. Sta. seed used, 1913	11.033	1.751	1.830	2.265	2.288	13.041	61.182	1.461	30.93	12.91	9.462	0.326	0.468
Kubanka, So. Dak. Expt. Sta. Crop, 1913.....	8.740	1.857	1.905	2.737	2.336	13.318	60.012	1.478	29.33	12.37	9.223	0.351	0.472
Egyptian, Del Norte.....	11.195	2.250	1.810	2.462	1.323	7.538	65.610	1.404	*	*	*	0.383	0.666
Durum N Egyptian, Del Norte.....	10.843	2.032	1.715	2.900	1.575	8.976	63.972	1.198	*	*	*	0.408	0.568

*We could not determine the gluten in Egyptian wheat.

GENERAL SAMPLES SPRING-WHEATS—CROPS 1912 AND 1913

	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio Gliadin to Glutenin Nitrogen	Total Nitrogen
Defiance, Ft. Collins, seed used.....	0.0314	0.1678	1.0031	1.0875	1:1.08	2.2898
Defiance, La Jara, 1912.....	0.0593	0.1328	0.5698	0.6922	1:1.21	1.4541
Defiance, Del Norte, 1912.....	0.0558	0.1238	0.7084	0.5548	1:0.78	1.4428
Defiance, Ft. Collins, not irrigated, 1913..	0.0593	0.2377	0.7049	1.4423	1:2.04	2.4442
Defiance, Grand Junction, 1912.....	0.0483	0.2028	0.9955	1.1950	1:1.20	2.4416
Defiance, Clifton, 1912	0.0804	0.1958	1.0007	1.2565	1:1.26	2.5334
Defiance, Ft. Collins, 1912.....	0.0628	0.2377	1.1674	1.1503	1:0.99	2.6183
Sonora, Del Norte, 1912.....	0.1014	0.1678	0.7327	0.9718	1:1.32	1.9737
Kubanka, Limon, dry land, 1912.....	0.0699	0.1958	0.9879	1.0244	1:1.04	2.2780
Red Fife, Ft. Collins, not irrigated, 1913...	0.0801	0.2587	1.0240	1.6444	1:1.60	3.0075
Red Fife, Ft. Collins, fallowed land, 1913..	0.0804	0.2237	1.0659	1.2973	1:1.21	2.6673
Marquis, Ft. Collins, fallowed land, 1913..	0.0839	0.2307	1.1417	1.3503	1:1.90	2.8067
Minn. Spring No. 1, Minneapolis, 1912.....	0.0558	0.2168	0.8203	1.1547	1:1.40	2.2476
Minn. Spring No. 2, Minneapolis, 1912.....	0.0663	0.2307	0.8564	1.0588	1:1.24	2.2122
Minn. Spring No. 3, Minneapolis, 1912.....	0.0558	0.1888	0.8063	1.0882	1:1.35	2.1391
Red Fife, So. Dak. Expt. Sta., Seed used...	0.0663	0.1958	0.9402	1.0470	1:1.11	2.2493
Red Fife, So. Dak. Expt. Sta. Crop of 1913..	0.0314	0.1608	0.8494	1.2855	1:1.51	2.3271
Kubanka, So. Dak. Expt. Sta. Seed used, 1912	0.0628	0.1818	0.9757	1.0581	1:1.08	2.2884
Kubanka, So. Dak. Expt. Sta. Crop of 1913	0.0488	0.1678	0.8040	1.3158	1:1.63	2.3364
Egyptian, Del Norte, 1912.....	0.1118	0.1238	0.3029	0.7840	.....	1.3225
Durum (Kubanka?)X Egpt. Del Norte, 1912	0.1118	0.1538	0.3751	0.9271	.....	1.5748

A STUDY OF COLORADO WHEAT

	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Turkey Red, Wellington, dry land.....	10.545	1.988	1.900	2.725	1.929	10.996	62.17	1.355	28.50	10.34	8.020	0.470	0.457
Turkey Red, Wray, dry land.....	10.155	1.888	1.723	2.487	1.779	10.138	66.04	1.455	20.53	7.87	6.196	0.427	0.456
Turkey Red, La Jara, yellow-berry.....	10.118	1.867	1.625	2.670	1.446	8.224	66.13	1.341	16.07	6.42	4.603	0.394	0.514
Turkey Red, Las Animas.....	11.468	1.844	1.540	2.440	2.007	11.441	63.07	1.283	24.63	9.85	7.132	0.471	0.470
Turkey Red, Weekel	9.425	1.493	1.465	2.708	2.335	13.311	64.37	1.272	28.00	10.98	8.453	0.294	0.350
Turkey Red, Clifton	9.708	.....	1.485	2.625	2.286	13.029	61.22	1.427	32.67	12.52	9.405	.....	.....
Kharkov, Ft. Collins.....	10.423	1.844	1.518	2.700	2.091	11.980	64.15	1.289	25.40	9.72	7.404	0.434	0.460
Kharkov, Ft. Collins.....	8.848	1.654	1.348	2.337	2.685	15.302	60.95	1.113	38.67	14.00	11.035	0.351	0.385
Jaroslov, Ft. Collins.....	8.639	1.665	1.360	2.582	2.802	15.970	59.11	1.187	40.73	15.04	11.344	0.362	0.389
Harvest King, Grand Junction, 1912.....	9.575	1.484	1.778	2.738	2.545	14.508	62.23	1.204	32.17	12.06	8.738	0.327	0.375
Harvest King, Ft. Collins.....	8.918	1.724	1.740	2.460	2.809	16.012	59.54	1.364	39.80	14.65	11.102	0.398	0.359
Red Cross, Fruita, 1912.....	9.485	1.481	1.775	2.337	2.483	14.150	63.07	1.404	28.30	11.13	8.271	0.261	0.364
Red Chaff, Eckert.....	10.743	1.681	1.763	2.677	1.764	10.052	65.54	1.461	21.53	8.57	6.265	0.388	0.416
Fultz, Ft. Collins.....	9.560	1.641	1.508	2.595	2.866	16.338	59.51	0.957	42.23	14.96	11.666	.....	.....
Big Frame, Ft. Collins.....	8.755	1.693	1.385	2.735	2.850	16.246	59.69	0.968	42.50	14.63	11.440	0.384	0.366
Prize Taker, Ft. Collins.....	8.690	1.528	1.878	2.400	2.492	14.206	62.30	1.068	34.50	12.98	9.639	0.306	0.324
Advance, Ft. Collins.....	8.718	1.672	1.623	2.830	2.674	15.244	60.66	0.870	37.30	14.16	10.694	0.366	0.371
Canadian Hybrid, Ft. Collins.....	8.630	1.502	1.605	2.475	2.773	16.806	61.63	1.115	36.57	14.35	11.066	0.328	0.369
Minnesota h. w. No. 2, Minneapolis.....	8.438	1.762	1.795	2.587	1.987	11.324	64.44	1.029	21.73	8.64	6.392	0.379	0.449
Minnesota h. w. No. 3, Minneapolis.....	8.375	2.092	1.685	2.725	1.887	10.755	64.01	0.924	21.87	8.99	6.686	0.477	0.437

COLORADO EXPERIMENT STATION

ANALYSES OF GENERAL SAMPLES WINTER-WHEAT—CROPS 1912 AND 1913

	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio Gliadin to Glutenin Nitrogen	Total Nitrogen Percent
Turkey Red, Wellington, dry land.....	0.0418	0.1818	0.8390	0.8666	1:1.03	1.9292
Turkey Red, Wray, dry land.....	0.0418	0.1468	0.4941	1.0958	1:2.22	1.7785
Turkey Red, La Jara.....	0.0453	0.1398	0.4719	0.7891	1:1.33	1.4461
Turkey Red, Las Animas.....	0.0628	0.1538	0.7434	1.0472	1:1.41	2.0072
Turkey Red, Weckel	0.0488	0.1748	0.9391	1.1726	1:1.25	2.3353
Turkey Red, Clifton	0.0593	0.1818	0.9192	1.1255	1:1.22	2.2858
Kharkov, Ft. Collins.....	0.0558	0.1468	0.8250	1.0636	1:1.17	2.0912
Kharkov, Ft. Collins	0.1468	0.1468	0.9529	1.4381	1:1.51	2.6846
Jaraslov, Ft. Collins.....	0.0593	0.2098	1.1663	1.3664	1:1.18	2.8018
Harvest King, Grand Junction.....	0.0558	0.2168	0.9880	1.2847	1:1.30	2.5453
Harvest King, Ft. Collins.....	0.0418	0.1818	1.2163	1.3693	1:1.14	2.8092
Red Cross, Fruita	0.0593	0.2237	1.0311	1.1684	1:1.13	2.4825
Red Chaff, Eckert	0.0628	0.1588	0.6642	0.8827	1:1.33	1.7635
Fultz, Ft. Collins.....	0.0663	0.2168	1.2105	1.3727	1:1.13	2.8663
Big Frame, Ft. Collins.....	0.0558	0.2168	1.2862	1.2915	1:1.00	2.8503
Prize Taker, Ft. Collins.....	0.0418	0.1748	0.9554	1.3202	1:1.38	2.4922
Advance, Ft. Collins.....	0.0349	0.1818	1.0068	1.3508	1:1.34	2.6743
Canadian Hybrid, Ft. Collins.....	0.0558	0.1888	1.0952	1.4332	1:1.31	2.7730
Minn. h.w. No. 2, Minneapolis.....	0.0314	0.1748	0.7003	1.0802	1:1.54	1.9867
Minn. h.w. No. 3, Minneapolis.....	0.0384	0.1888	0.7592	0.9005	1:1.18	1.8869

GENERAL SAMPLES FOR 1914

	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Spring Wheats													
Defiance, Eckert, yellow-berry very bad.....	9.313	1.892	1.858	3.095	1.974	11.252	64.638	1.452	28.37	12.49	8.093	0.433	0.597
Defiance, Ft. Collins, fallow, wet in shock.....	8.428	1.708	1.933	3.555	2.075	11.825	60.822	1.063	31.33	13.30	9.293	0.322	0.393
Defiance, Ft. Collins, fallow, not wet.....	8.465	1.643	2.018	3.512	2.113	12.044	62.064	1.068	32.00	12.99	9.076	0.326	0.430
Marquis, Ft. Collins, fallow, wet in shock.....	8.965	1.508	2.140	3.257	2.419	13.788	59.148	1.065	40.83	16.44	11.393	0.333	0.340
Marquis, Ft. Collins, fallow, not wet.....	8.460	1.448	2.165	3.320	2.468	14.065	60.210	1.157	40.40	16.40	11.589	0.338	0.364
Red Fife, Ft. Collins, fallow, wet in shock.....	8.985	1.813	2.015	3.292	2.492	13.477	58.728	1.099	42.17	16.24	11.398	0.332	0.377
Red Fife, Ft. Collins, fallow, not wet.....	8.184	1.588	2.015	3.447	2.596	14.794	60.486	1.241	43.20	16.90	11.781	0.350	0.502
Winter Wheats													
Red Chaff, Eckert, yellow-berry very bad.....	9.855	1.587	2.145	3.062	1.411	8.043	64.458	1.352	17.63	7.20	4.935	0.367	0.535
Turkey Red, Fruita, yellow-berry in all.....	10.215	1.647	1.540	2.940	1.693	9.647	64.638	1.068	24.37	10.06	7.063	0.345	0.561
Turkey Red, Fruita, yellow-berry in all.....	9.213	1.566	1.610	2.952	1.765	10.050	65.250	1.215	26.66	10.67	7.750	0.309	0.539
Turkey Red, Fruita, no yellow-berry.....	8.675	1.295	1.633	2.956	2.318	13.210	61.740	1.142	37.60	15.49	11.313	0.231	0.485
Big Frame, Ft. Collins, wet in shock.....	9.053	1.626	1.480	3.122	2.509	14.301	59.976	1.241	42.00	15.95	11.672	0.359	0.477
Fultz Mediterranean, Ft. Collins, wet in shock	9.460	1.601	1.583	2.960	2.457	14.002	61.106	1.184	42.00	16.31	11.909	0.364	0.504
Prize Taker, Ft. Collins, wet in shock.....	9.488	1.633	1.843	2.862	2.286	13.031	60.570	1.263	37.50	14.82	10.853	0.371	0.484
Harvest King, Ft. Collins, wet in shock.....	9.298	1.648	1.713	2.605	2.270	12.936	62.262	1.356	41.63	16.28	11.455	0.376	0.483
Jaraslov, Ft. Collins, wet in shock.....	9.305	1.503	1.793	2.912	2.631	14.994	59.040	1.031	48.83	18.15	13.488	0.333	0.465
Kharkov, Ft. Collins, wet in shock.....	9.485	1.615	1.460	2.875	2.446	13.942	59.886	1.003	44.90	16.19	11.822	0.346	0.534

GENERAL SAMPLES SEASON 1914

	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio of Gliadin to Glutenin Nitrogen	Total Nitrogen Percent
Spring Wheats						
Defiance, Eckert, yellow-berry, very bad.....	0.0769	0.1888	0.7712	0.9371	1:1.21	1.9740
Defiance, Ft. Collins, fallowed ground, wet in shock	0.0384	0.2098	0.9728	0.8535	1:0.88	2.0745
Defiance, Ft. Collins, fallowed ground, not wet....	0.0384	0.2098	1.2577	0.6171	1:0.49	2.1130
Marquis, Ft. Collins, fallowed ground, wet in shock.	0.0488	0.2517	1.1954	0.9231	1:0.79	2.4190
Marquis, Ft. Collins, fallowed ground not wet in shock	0.0523	0.2587	1.2012	0.9553	1:0.79	2.4675
Red Fife, Ft. Collins, fallowed ground, wet in shock	0.0523	0.2587	1.1169	1.0636	1:0.95	2.4915
Red Fife, Ft. Collins, fallowed ground, not wet.....	0.0558	0.2517	1.0812	1.2067	1:1.12	2.5955
Winter Wheats						
Red Chaff, Eckert, yellow-berry very bad.....	0.0769	0.1538	0.4543	0.7260	1:1.20	1.4110
Turkey Red, Fruita, all affected with yellow-berry...	0.1188	0.1608	0.6175	0.7954	1:1.45	1.6925
Turkey Red, Fruita, no yellow-berry.....	0.0769	0.2098	1.0787	0.9521	1:0.88	2.3175
Turkey Red, Fruita, all affected with yellow-berry...	0.1188	0.1678	0.6781	0.8003	1:1.19	1.7650
Big Frame, Ft. Collins, wet in shock.....	0.0804	0.2307	0.9868	1.2111	1:1.23	2.5090
Fultz Mediterranean, Ft. Collins, wet in shock....	0.0593	0.2307	1.1383	1.0282	1:0.90	2.4565
Prize Taker, Ft. Collins, wet in shock.....	0.0699	0.2447	1.0811	0.9803	1:0.82	2.2860
Harvest King, Ft. Collins, wet in shock.....	0.0558	0.2656	1.2723	1.0368	1:0.82	2.6305
Kharkov, Ft. Collins, wet in shock.....	0.0628	0.2377	1.1301	1.0154	1:0.90	2.4460

A STUDY OF COLORADO WHEAT

	Sp. gr.	SiO ₂ Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Red Fife, not irrigated and not fertilized, Ft. Collins, 1913.....	1.4383	0.116	0.012	present	0.050	0.129	0.357	0.002	.....	0.105	0.293	0.025	0.268	2.700
Defiance, not irrigated and not fertilized, Ft. Collins, 1913.....	1.4317	0.053	0.009	present	0.042	0.138	0.343	0.008	.....	0.093	0.336	0.015	0.321	2.444
Harvest King, winter wheat, Fruita, 1912	1.4165	0.026	0.007	present	0.038	0.116	0.375	?	0.087	0.101	0.327	0.020	0.307	2.545
Defiance, 4½ miles east of Fruita, 1912	1.4055	0.034	0.009	present	0.033	0.119	0.431	0.007	0.118	0.141	0.271	0.012	0.259	2.442
Defiance, Clifton, 1912.....	1.4327	0.038	0.007	present	0.029	0.141	0.400	?	0.165	0.155	0.329	0.015	0.314	2.534
Red Cross, 2½ N.E. of Fruita, winter wheat	1.4237	0.038	0.007	present	0.025	0.120	0.364	0.009	0.086	0.175	0.261	0.014	0.247	2.483
Red Fife, So. Dak. Expt. Sta. (Seed Wheat), 1912	1.4127	0.018	0.005	0.005	0.044	0.134	0.490	?	0.072	0.133	0.279	0.011	0.268	2.248
Kubanka, So. Dak. Expt. Sta. (Seed Wheat), 1912	1.4334	0.011	0.006	0.005	0.026	0.141	0.468	?	0.064	0.145	0.326	0.012	0.314	2.282
Defiance, fallowed ground, Ft. Collins, 1912	1.4298	0.009	0.005	present	0.043	0.150	0.414	0.020	0.060	0.157	0.376	0.017	0.359	2.618
Red Fife, fallowed ground, Ft. Collins, 1913	1.4352	0.007	0.007	present	0.037	0.162	0.380	0.020	0.059	0.146	0.414	0.025	0.389	3.008
Marquis, fallowed ground, Ft. Collins, 1913	1.4334	0.006	0.007	present	0.041	0.155	0.409	0.023	0.056	0.132	0.402	0.022	0.380	2.804
Minnesota, Hard Spring No. 1, 1912...	1.4195	0.029	0.005	0.006	0.044	0.135	0.438	0.008	0.071	0.128	0.418	0.027	0.391	2.248
Minnesota, Hard Spring No. 2, 1912...	1.4049	0.018	0.004	0.006	0.027	0.149	0.439	0.025	0.076	0.144	0.381	0.026	0.355	2.213
Crop of 1914														
Defiance, Ft. Collins, cultivated fallow one year	1.3619	0.016	0.006	0.005	0.037	0.150	0.393	0.009	0.192	0.127	0.322	0.009	0.313	2.075
Marquis, Ft. Collins, cultivated fallow one year	1.3981	0.012	0.005	0.005	0.036	0.130	0.340	0.028	0.081	0.162	0.333	0.014	0.319	2.419
Red Fife, Ft. Collins, cultivated fallow one year.....	1.4259	0.018	0.005	0.007	0.030	0.147	0.377	0.028	0.119	0.184	0.332	0.015	0.317	2.517

I have given the analyses of general samples of spring- and winter-wheats in the preceding tables in order to convey a general idea of what the composition of Colorado wheats really may be. Some of the samples analyzed were from Minnesota; these have been introduced simply for comparison. It is true that I could have found analyses of Minnesota wheats, but I wanted analyses made by the same analyst, to eliminate personal equations. The South Dakota samples are introduced because we used their crops of 1912 as seed wheats. Their samples of the 1913 crop were obtained to see how their crops for this year compare in composition with the preceding, as well as with our own. I do not know how the seasons differed in South Dakota nor how they differed from ours, besides, our wheats were grown with, and theirs without irrigation.

I fully realize that it is almost useless to try to compare wheats grown in different localities, as the composition evidently depends upon so many conditions that cannot be given in the statement of the analyses, that differences in the composition cannot readily be interpreted. As an illustration of this, the three samples of Turkey Red wheat given in the table of winter-wheats, General Samples of 1914, serve very well. These are samples labeled "Fruita", which I personally collected. Two of these samples were grown within one-half mile of one another, while the third sample was grown a short distance east of these in the same district. I was informed that these growers received seed from the same lot. These three samples were produced under the same conditions of weather; they were all threshed directly from the field. The grains were all protected from the weather, in fact were stored in granaries and they were all grown with irrigation. I do not know definitely, but I think it quite safe to assume, that they were grown with one irrigation, and without any fertilization. So far, the conditions under which the three samples were grown may be considered as identical and yet their composition is very different. This is not only the case with the protein, which is 9.6, 10.1 and 13.2 percent respectively, but we find the phosphorus and potassium varying to a significant extent, but inversely with the protein content. Were it not for my personal knowledge of the soil conditions, and of the other conditions as well, the analytical results obtained in these cases would be impossible of interpretation. This pertains to all general samples with much force. I am so fully convinced that it is wholly useless to try to interpret an analysis of a wheat, without a rather full knowledge of the conditions under which the sample was grown, that I have sought no general samples during the past year and a very few in the past two years. As a further justification for this conviction I may cite the case of two samples given in the table of general samples of spring-

wheats for 1913 and a sample of Red Fife to be given in a subsequent table, all grown in 1913 under identical conditions of weather and irrigation and within less than 100 feet of one another on two contiguous and uniform plots of land. We have in the first pair, Red Fife, protein 17.143; Marquis, protein 15.998. The third one is a sample of Red Fife with 13.442 percent of protein. The differences in the amounts of phosphorus and potassium present are, again, big, and roughly, inversely proportional to the protein present. I shall endeavor to explain these differences in the proper place.

It becomes a question what the value of an analysis of a general sample of wheat, as a representative of the product of a county or a state, may be. It is only by the intelligent selection and analysis of a very large number of samples that a reasonably accurate estimate of the quality of the product of a good-sized county can be obtained. In our table of general samples of spring-wheats, rejecting the Egyptian, we have a range of protein from 8.224 to 17.143 percent and of true gluten from 4.001 to 11.593 percent. These figures represent different varieties, but we find for the same variety a range from 4.001 to 9.723 percent of true gluten calculated on the air-dried wheat. These differences correspond to a wide range of conditions of climate, soil, and very probably of cultivation. In the San Luis Valley, for instance, we have an altitude of 7,500 feet with its own peculiar climate and soil, and at Fort Collins we have an altitude of 5,000 feet with its climate and soil. While the San Luis Valley is 2,500 feet higher than Fort Collins, it is about 200 miles further south. The San Luis Valley has a rainfall of about 7.0 inches and the Fort Collins section one of 14.9 inches. Neither section as a rule can grow spring-wheat without irrigation. The wheats produced cannot be compared in regard to composition unless all of the conditions are given with the samples.

The Minnesota samples, analyses of which are given in the preceding table, were kindly sent to me, on request, by Mr. G. H. Tunell of the Minnesota Grain Inspection Department. I desired to see samples of their grading and also to have our own analyses of these wheats, because the high quality of their flours, made from hard spring-wheats is, I believe, universally recognized. I, however, know nothing of the conditions under which they were grown and we do not know to what extent these samples are comparable to ours, or are representative of Minnesota wheats. I am not certain about the variety, but I would judge this to be Red Fife. So far as analytical results are concerned these samples are not equal to the majority of the Colorado samples. We have only two of the general samples of Colorado wheats which appear to be of materially lower quality than these Minnesota samples,

and these two are samples of Defiance wheat grown at La Jara and Del Norte in the San Luis Valley. Both of these samples represent extreme cases of yellow-berry or mealiness and are, for this reason, perhaps, inferior to the Minnesota samples which are flinty wheats.

I have already stated in another place that the Minnesota flour is preferred by our bakers for bread-making, as it yields from 30 to 40 more loaves per barrel than our own. Assuming these samples of wheat to be representative, this opinion is contrary to the analytical results. At the present time I am inclined to accept the bakers' judgment as the more reliable criterion. The differences in the amounts of the mineral substances in the wheats are so small that it is difficult to interpret them, though they, without doubt, are significant. The range in phosphorus, for instance, in the thirteen cases in which we have given the mineral constituents, is equal to 0.151 percent of the air-dried wheat, but this is 60 percent of the minimum amount of phosphorus found in these samples and indicates a great difference in the nutrition of the plants.

While the value of general samples, without a definite statement of the conditions under which they were grown, may be small in the way of indicating the general character of the wheat grown in any considerable section of the country, still, they may have a little value in showing the range in composition. It is for this reason that I have given the 50 odd analyses of general samples, including 5 samples from Minnesota and 4 from South Dakota. The South Dakota samples were introduced for the further reason that we used their wheat of the 1912 crop as seed in our experiments.

WHAT ANALYSES SHOW

These analyses show that our wheats often contain large percentages of nitrogen and also that the true gluten is high. They are even richer in these substances than our samples' from the other two states. Further, that the ratio of gliadin nitrogen to glutenin nitrogen falls well within the limits accepted for good flours. On the other hand these samples show that some of our wheats are low in nitrogen, but these have a fairly good gliadin-glutenin ratio. This may have no more than an analytical significance, but this is all that we, at the present time, care to consider, as we intend to divorce composition and quality as far as possible in this bulletin. It may well be that these are so intimately related that they ought not to be considered separately, still our purpose is to confine our consideration to the composition of our samples and the factors that affect it, leaving the question of quality for a subsequent time.

There are only a few samples among those given, which were grown on "dry land", or without irrigation, but, so far as we can attach any value to so small a number of samples, we find no justification for the claim which is sometimes made, that dry land wheat is better, i.e., richer in nitrogen than irrigated wheat. This sentence is written with the knowledge that it is opposed by the views of very competent men either directly or by intimation. Schindler, for instance, holds that hot, dry summers produce wheats high in nitrogen as compared with the same variety grown in cooler and wetter summers or localities. This seems to be, at least it is accepted, as an established fact, but it is not applicable to our conditions, concerning which we shall have more to say at another time.

The general samples of wheat from the same locality, as well as from different localities, are readily separated into classes according to their flintiness or starchiness. The flinty kernels, on the one hand, are rich in nitrogen, the starchy ones, on the other hand, are poorer in nitrogen. I do not know when or by whom this observation was first made, but it is a very widely recognized property of wheat kernels. Ritthausen and Dr. R. Pott mentioned such kernels in 1872 * and this condition is described quite fully by Schindler in his "Getreidebau"† where he says: "'Flinty' wheat is, on account of its greater density, i.e., its high specific gravity, designated hard wheat and is, as a rule, richer in nitrogen, and the amount of gluten is greater than in the mealy, or so called soft wheats" to which he adds in a footnote "This is also the case even when the flinty and starchy kernels are of the same variety and have been produced in the same field; in this case, the kernels produced in the top and bottom portions of the head are apt to be more flinty and those in the middle portions more mealy. P. Holdefleiss§ found that in one and the same crop of Early Bastardweizens the flinty kernels contained 1.907 percent nitrogen (12.23 percent protein) the mealy ones, on the contrary, 1.566 percent nitrogen (9.79 percent protein)."

The physical property of the kernels first mentioned is not characteristic of any locality, but is found distributed everywhere throughout the State, so far as my knowledge of the wheats produced extends. We find, that the chemical composition varies with this, but this does not prove that the bread-making qualities are lessened, though the gluten content certainly varies, as well as the chemical composition. There is no doubt but that physical properties and chemical composition are dependent upon conditions of fertility which vary from place to place in small areas and even more in large ones, especially in a State of

* Die landwirtschaftlichen Versuchs-Stationen Band XVI, p. 391.

† Schindler, Der Getreidebau, 1909, p. 151.

§ P. Holdefleiss, "Mehligkeit und Glasigkeit der Weizenkoerner." "J. Kuehns Berichte," XIV, 1900.

such varied physical conditions as we have in Colorado. It is not only a question of climate, especially of rainfall and seasonal differences due to altitude, but also a question of soil. The soil of the San Luis Valley, for instance, is very different from that of the Arkansas Valley, or of the Grand Valley, in its origin and in its properties. The climates, too, of these valleys are very different. The San Luis Valley has an altitude of 7,500, the Grand Valley about 4,000 and the eastern portions of the Arkansas Valley about 3,000. They differ further in this, that the San Luis Valley is surrounded by high mountains. The range on the east side of it, the Sangre de Cristo, is very high, possibly the highest in the State. Mount Blanca, its highest peak, attaining a height of 14,467 feet, while Las Animas, in the Arkansas Valley, is some 140 miles east of the mountains in the plains section and approximately 4,500 feet lower. Irrigation is necessary in both sections.

No reasonable number of general samples grown under such a variety of conditions, including both soil and climate, can give any definite information concerning the character of the wheat grown in the State. The only thing that would be feasible, would be to study the grain produced in some definite section whose conditions of soil and climate could be given. I, at first, thought that it might be possible for us to obtain enough samples from reliable parties to accomplish this broader purpose in a reasonably satisfactory manner. It would serve no good purpose to give all of the considerations which have lead us to abandon this notion. Those given must satisfy the reader, as they have sufficed to convince us that it is wise on our part to acknowledge our change of attitude. The facts stated give our reasons for presenting so few general samples in 1914 and none in 1915. Further, they explain why we have confined our efforts to the study of our own samples grown under fairly well known conditions.

YELLOW-BERRY

It will be noticed that the samples of Defiance from various localities differ by a maximum of 6.859 percent of protein or 1.206 percent of nitrogen. The physical properties of the kernels indicated a very decided difference in these samples; those from La Jara and Del Norte present large, plump, mealy kernels, that from Del Norte weighing 49.07 grains per 1,000 kernels. There were no flinty or part flinty kernels in this sample. It is an extreme case of yellow-berry wheat. The sample from Fort Collins presents smaller, somewhat shrunken, flinty kernels which weigh 30.65 grams per 1,000; in the former sam-

ple we have 8.054 percent protein ($N \times 5.7$) and in the latter 14.923 percent. In the La Jara sample, with 8.288 percent protein, the kernels are smaller than in the Del Norte sample. There are a few berries which cannot be classed as either flinty or mealy, though the berry is uniform in appearance. This is not the case in many other samples, for in these the kernels show distinct areas of mealiness, sharply contrasting with the flinty character of the rest of the kernel. This condition is not confined to any one variety of either spring or winter-wheats. We have previously mentioned the differences in composition of three samples of a winter-wheat, Turkey Red, for which we gave the protein as 9.6, 10.0 and 13.2 percent, showing a difference of 3.6 percent in the protein present. These samples were grown, according to my information, from the same lot of seed and in the immediate neighborhood of one another—the second and third samples within one-half mile of one another. The physical properties of these samples are just as distinct as are those of the Defiance samples previously given.

It seems proper to consider this subject in this connection, because it is the most patent condition occurring in our general samples, corresponding to a marked difference in composition. Kosutany, Schindler, and such other European writers as I have read, do not formulate a definite cause for this condition, though they repeatedly refer to it. The general explanation which runs through Schindler's book, "*Der Weizen in seinen Beziehungen zum Klima*," is that it is dependent upon climate, particularly upon moisture. On page 76 of the work just mentioned he says:* "The processes of carbohydrate formation, as well as the deposition in receptacles for the same, depend in the highest degree upon climatic factors, but the soil, the only source of nitrogen for the cereals, is the first of all (factors) in the (formation) of protein. The absolute quantity of protein in wheat depends upon this (the soil supply) and can be regulated by the application of nitrogen, but the relative amount is determined by the climate." This author has previously stated, page 41: "However fragmentary the cited material may be, one fact of fundamental significance is shown thereby, i.e., that the absolute weight of wheat (weight of 1,000 kernels) stands in a definite, independent relation to the external conditions of growth, among which, climate excels all others in influence." These quotations suffice to show that the author considers climate as the most important factor in determining the ratio between the protein and carbohydrates in the wheat kernels. While this author designates kernels as flinty, mealy, and half mealy, he does not definitely state that climate causes mealiness, but he says, as quoted above,

* In the quotations from Schindler I have given the title and page of the German work but not the text. The translation is the author's.

that the relative amount of nitrogen is determined by the climate. Lawes and Gilbert, in an article entitled, "Our Climate and Our Wheat-Crops",* quote from a preceding article which appeared in the Journal of the Royal Agricultural Society of England Vol. IX, Part 1, p. 96: "Thus it is obvious that different seasons will differ almost infinitely at each succeeding period of their advance, and that with each variation the character of development of the plant will also vary, tending to luxuriance, or to maturation, that is, to quantity or to quality as the case may be. Thence, only a very detailed consideration of climatic statistics, taken together with careful periodic observations in the field, can afford a really clear perception of the connection between the ever fluctuating characters of season and the equally fluctuating characters of growth and produce. It is, in fact, the distribution of the various elements making up the season, their mutual adaptations, and their adaptation to the growth of the plant which throughout influence the tendency to produce quantity or quality. It not infrequently happens, too, that some passing conditions, not indicated by a summary of the meteorological registry, may affect the crop very strikingly; and thus the cause will be overlooked, unless observations also be made and the stage of progress and tendencies of growth of the crop itself at the time, be likewise taken into account." This article reviews the weather conditions and the wheat crops in England from 1816 to 1879, but more particularly from 1843-44 till 1878-79. During the latter period they select six seasons during which the yield of straw and grain were both high, four seasons with high yield of grain and low yield of straw, and four seasons during which the total produce was low. They give the total number of rainy days, i.e., days on which 0.01 inch or more of rain fell. With 140 rainy days the yield of both straw and grain was high. With 136 rainy days the yield of grain was high, of straw low. With 199 rainy days the total produce was low. In discussing the wheat crop of 1878-79 at Rothamsted, one of the poorest crops on record at that time, they had 226 rainy days, with 42.29 inches of rainfall. In comparing the two very bad seasons of 1816 and 1879 these authors conclude: "Lastly, it would appear that any defect of our climate in appropriateness for the production of full and well-matured wheat crops is more connected with an excess of rain and consequent wetness of soil and humidity of atmosphere, than with any deficiency of average summer temperature." In regard to the yield of grain in 1879, it appears from the data given that it was about one-half of the average crop for the preceding 27 years. In regard to quality, the weight per bushel seems to have been taken as the measure. In fact, so far as I can gather, they use the terms "quality" and "weight per

* Rothamsted Memoirs, Vol. V. 11th Article, p. 4. or Journal Roy. Ag. Soc. Eng. Vol. XVI, s. s. Part 1, p. 173.

bushel" synonymously. The weights per bushel given for the season of 1879 range from 2.7 to 5.4 pounds below the average for wheat grown under the same conditions of manuring for the preceding 27 years. That this is what is understood by quality in this case, seems apparent from the manner in which they refer to it. They say: "The defect in weight per bushel of the dressed corn was great under all the conditions cited."

"Lastly, great as was the deficiency in the produce of corn, and in the weight per bushel of dressed corn, under all the conditions, the proportional deficiency of straw was much less."

After discussing the conditions under which the crop of 1878-79 was grown they add: "Thus, the plant, which luxuriates in a comparatively dry soil and climate passed its whole existence under exactly opposite conditions; and the result was only what was to be expected."

"It has of course long been known that an excess of wet is injurious to the wheat crop, but it is only comparatively recently that one at least of the material causes of the adverse influence has been made out; namely, the great loss of nitrogen carried off by drainage in the form of nitrates."

These authors clearly hold that the weather conditions, especially the mean temperature and rainfall, exercise a big influence upon the yield and quality of wheat, meaning by quality, primarily, weight per bushel. They further assign as one cause of this, the removal of nitrates by the leaching action of excessive rainfall. The same authors return to this subject in a subsequent article "On the Continuous Growth of Wheat, etc., from 1864 to 1883".*

"We find the two crops running a parallel course, showing great differences in their yield as the seasons are favorable or unfavorable. The Rothamsted soil, like a great many cultivated soils, contains a large amount of mineral food of plants: it also contains organic nitrogen, that is to say, nitrogen in combination with carbon, the residue of previous vegetation. This organic nitrogen does not appear to be available as food for the wheat plant, but every year a certain amount of it is converted into nitric acid, which combines with the lime in the soil. In this state it is very soluble in water, is readily washed out of the soil by heavy rain, and, further, is a most important and essential food of the wheat plant."

"The amount of nitric acid formed each year will vary, the formation being the most rapid in the hottest weather, provided the soil is sufficiently moist. The amount of nitric acid which the wheat crop can take up will also vary, and in a cold and wet winter much will be washed beyond the reach of the roots of the plants."

* Rothamsted Memoirs, Vol. VI., 3rd Article, p. 44. This originally appeared in the Jour. Roy. Ag. Soc. Eng. Vol. XX, s. s. Part. II.

"These facts, which are of universal application, enable us to explain some of the causes which tend to the production of good or bad crops of wheat."

In discussing the good crops of 1858 and 1863, they go further in discussing the general composition of the grain than in the preceding quotations and give us another view of how the weather affects this. In the preceding quotations they speak of good and bad crops without special consideration of the composition of the grain, but in the following quotations they include the latter: "It will afterward be seen, indeed, that the total crop of 1863 contained about one and one-half time as much mineral matter per acre, and also considerably more nitrogen than that of either of the other seasons (1852, 1856, 1858): yet the percentage of both was much lower in the grain, and that of the nitrogen lower also in the straw, than in the produce in either of the other years. There is here again evidence that with favorable maturation there is low percentage of both mineral matter and nitrogen; that is, favorable maturation means the greater accumulation of non-nitrogenous organic substances, carbohydrates and especially starch,—the result necessarily being a lowering of the proportion though not of the actual amount of both the nitrogenous and mineral constituents." These authors have been quoted already as attributing the defect of their climate, in regard to the wheat crop, to an excess of rain rather than to a deficiency in the mean temperature. They attribute the effects of excessive moisture to two principal facts, first, to the preference of the plant itself for a dry rather than a wet soil, and second, to the leaching out of the nitrates.

Lawes and Gilbert, it appears, have written exclusively of winter-wheat which, in England, seems to have a very long growing period, as they speak of August as their harvest period. They make no distinction between flinty and mealy kernels, as the German writers do. I am unfortunately not familiar with the English wheats and have seen but few samples of European wheats, but the Swedish, Dutch and French wheats that I have seen were mealy wheats and that to such an extent that one could not distinguish the kernels as having distinct characteristics, as flinty and mealy. This may be the case with the English wheats, but one would scarcely think that it would be the case with all of their samples, which were grown with such a variety of manuring. Still, they use the weight per bushel as indicative of quality; the only exception to this statement is in the quotation just made defining favorable maturation, "That is, favorable maturation means the greater accumulation of non-nitrogenous organic substances,—carbohydrates and especially starch,—the result necessarily being a lowering of the proportion, though not of the actual amount of both the nitrogenous and the mineral constituents." Even in this statement it is not clear that their statement can be construed as distinguishing between flinty and mealy

wheats. I am inclined to think that it is a general statement without distinction of any special physical properties. The principal point in all of this, however, is evident, that they consider the weather conditions as determining the quality and quantity of their crops.

I believe that all of the publications upon this subject that have appeared in this country have adopted the same general views, to which, in a certain measure, we must subscribe, for it is evident, without statement, that the growth of the plant and the quality of the product is dependent in a measure upon weather conditions, i.e., upon accidental conditions from year to year. There are, however, some characteristics of the grain which are neither determined nor obliterated by the weather conditions, though they have been very largely attributed to the latter. Kosutany and also Schindler attribute, in an indefinite way, influence to the soil, but the latter, especially, attributes a predominating influence to the climate, and he uses the term in its larger sense.

The writers in this country go, perhaps, even farther in attributing to climatic influences, a determining influence upon the character of the grain produced. I would like to mention all of these writers but there are too many of them. The only one among them who, so far as I know, attaches any considerable influence to soil fertility is Snyder, formerly of Minnesota. The views of the great majority of the rest of these writers are represented by the statements of Le Clerc of the Bureau of Chemistry of the U. S. Department of Agriculture in Bulletin 128, from which the following quotations are made: "Eckenbrecher* grew six varieties of barley in twelve different localities and found that the same variety showed a much larger variation in nitrogen content and in weight per 1000 grains when grown in the twelve localities than the six varieties did when grown in any one locality, that is, that climatic conditions, or environment, exerted a greater influence than did the seed or even the variety. Yet Hall in the article just quoted† makes the statement that variety is the chief factor in affecting the composition of plants, that each race or variety possesses characteristics which are modified only to a relatively slight extent by soil, seed, or climate".§

"Bogdan found that an increase of salt content of alkali soils produced an increase in the nitrogen and ash content of wheat though the absolute amount of these constituents decreased due to the fact that the grains were smaller. This, in a certain way, explains the good quality of the rather small grains of wheat grown in southeastern Russia, northwestern America, Hungary etc., where the soil is rich in soluble salts, especially nitrates. It has, however, generally been assumed that fertilizers influence the yield

* Wockenschrift Brau, 1907, 24-491.

† Science 1905-22-461.

§ Bul. 128, Bureau of Chemistry, U. S. D. A., p. 8.

considerably and to a small extent the composition. In like manner, soil is one of the lesser factors affecting the composition of wheat. This is the opinion of Lawes and Gilbert, Hall, Wiley, and others; though, of course, a nitrogen-rich soil will yield a crop of a somewhat greater nitrogen content than will a nitrogen poor soil.”*

The conclusions reached in this bulletin may be taken as reflecting the opinion of, at least, a very large percentage of our writers. They are formulated as follows:

“Wheats of the same variety when grown in the same locality and under the same conditions are, therefore, seen to vary but little in composition although coming from seed differing widely in physical and chemical characteristics. These results are corroborative of Eckenbrecher’s work with barley and are entirely at variance with Hall’s statement that each race or variety possesses qualities which are modified only to a slight degree by seed, soil, or climate. Wheat of any one variety, from any one source and absolutely alike in chemical and physical characteristics, when grown in different localities, possessing different climatic conditions, yields crops of very widely different appearance and very different in chemical composition. The results so far obtained would seem to indicate that the soil and seed play a relatively small part in influencing the composition of crops.”†

These quotations from Le Clerc may be taken as fairly representative of the views generally obtaining among our writers on this subject. The terms climatic conditions and environment are not used with such definiteness that one can always tell just what is meant, in fact they are sometimes used as alternative expressions of climatic conditions or environment. Again, the latter term is used in a more comprehensive sense, taking in rainfall, sunshine, temperature, winds, humidity of the air, soil, time of planting, cultivation, manuring, thickness of seeding, previous crops, etc.

I have deemed it wise to state these general views which are very commonly held by students of this subject.

THE EFFECT OF CLIMATE ON COMPOSITION

The explanation that I have offered for yellow-berry in wheat is not in harmony with the statements just made, nor are they in harmony with other explanations offered, which belong to several classes; for instance, the result of injury by fungi, unseasonable harvesting and exposure to the weather after cutting, to heredity or a “tendency” herit-

* Bul. 128, Bureau of Chemistry, U. S. D. A., p. 9.

† Bul. 128, Bureau of Chemistry, U. S. D. A., p. 18.

able in wheat, and to climatic conditions. Under the latter head I suppose the principal factor considered is the rainfall or supply of water. Again, I know of no one more explicit in his statements than Le Clerc, who discusses with clearness flinty and mealy wheats. He says: "Furthermore the wheat of the humid regions contains a larger percentage of mealy kernels showing that there is a very close relation between the percentage of protein and the percentage of flinty grains, that is, generally, the more flinty the kernels the higher is the percentage of protein. An excessive amount of rainfall or irrigation is almost always accompanied by a crop containing a low percentage of protein. This is further shown in the work done in 14 different localities in the far Western states, 7 of these places were irrigated and the percentage of protein averaged 12.1 while in the 7 places where no irrigation was practiced the protein content of the wheat was 15.4 percent."* In the next paragraph he describes two samples of wheat of which he says: "The non-irrigated samples consisted of flinty kernels entirely and contained 5.4 percent more protein than the original seed and 6.6 percent more protein than the irrigated sample. The irrigated sample contained, moreover, very few flinty kernels (only 20 percent)." Again, in commenting on the observations of Lawes and Gilbert he writes: "The six seasons of bad crops showed rain to have fallen during each of the 199 days. The seasons of good crops had but 136 days during which it rained."† The probable reason for such differences is that an excessive rainfall dilutes the nitrates in the soil too much and there being but small amounts of carbohydrates in the process of formation, owing to lack of sunshine, less protein is formed. The result is a mealy grain of low protein content."§ In the same article is given excellent illustrations of flinty, half-flinty and mealy kernels and in the legends we find "Flinty wheat grain grown under dry farming", "Starchy wheat grain grown under excessive irrigation". If there were any doubt remaining in regard to what the author considered the cause of the mealiness of some kernels this would remove it.

TOO MUCH IMPORTANCE ATTACHED TO CLIMATE

In Bulletin 205 I showed that this condition is not due to injury by fungi, nor to the time of cutting, nor to weathering, nor to climatic conditions, etc. The answer to these suggestions is given by pointing out the fact that we can produce flinty kernels by applying nitrates or increase the percentage of mealy berries by increasing the supply of potassium. While I do not for one moment doubt the importance of favorable weather conditions in the production of a good crop of wheat, I am convinced that too much importance has been attributed to this group of agents over and against the influence of the soil con-

* Yearbook, U. S. D. A., 1906, p. 203.

† Yearbook, U. S. D. A., 1906, p. 205.

§ There were 199 and 136 days respectively on which 0.01 inch or more of rain fell. These are the mean number of days for each period.

ditions. While there is no doubt but that lack of sunshine and excessive moisture, especially as rainfall, influence the composition of the wheat kernel, it is probably seldom the case that it goes so far as to determine the flintiness or mealiness of the kernel, or if it does, it is probably by its direct influence upon the food supply in the soil in washing the nitrates below the feeding area of the plant roots, rather than by its direct action upon the plant itself. There is no doubt but that these agents, frequent rains and cloudy weather, have a direct influence upon the plant which follows from the data given in our Bulletin 217, but it is not so great nor in the direction assigned to it in these quotations. We shall further give some data to show that it is difficult to remove enough nitrates by the application of water to produce the effects attributed to it, and it is for this reason that I have just said that it is probably seldom the case that it goes so far as to determine the flintiness or mealiness of the kernel. This effect of excessive rain, the washing out or reducing the amount of nitrates in the soil, was pointed out by Lawes and Gilbert in their article "Our Climate and Our Wheat-Crops" and again, in the article "On the Rain and Drainage Waters of Rothamsted".

I wish in this connection to emphasize the statement previously insisted upon that analytical results obtained with samples of wheats unaccompanied by a full account of all of the conditions under which they were grown are too difficult of correct interpretation to justify reliance upon any interpretation offered for such analytical facts. In this connection I appreciate that the conditions under which the crops of which Lawes and Gilbert wrote, grew, were wholly different from those under which my samples were grown. They wrote of winter-wheat which seemingly had a growing period, i.e., from planting till harvest, of ten months or more. My observations have been made, principally, on spring-wheats with growing periods varying from 101 to 128 days. The rainfall given for 1878-79 at Rothamsted is 42.29 inches. The average annual rainfall at Fort Collins is 14.9 inches, in the exceptional year of 1915 it was about 22.5 inches. The rainfall during the total growing period of our spring-wheat is usually about 7 inches; in 1915 it was a little over 13 inches. Our mean temperature for the growing period is higher than the mean temperature under which their crops were grown. It would seem to be unnecessary to state these facts, but it is, perhaps, wise to do so lest it be thought that I failed to consider them.

EFFECTS OF NITROGEN AND PHOSPHORUS ON FLINTINESS OR MEALINESS

In Bulletin 205 I aimed to do exactly what is suggested by its title, to point out the cause of flintiness and mealiness in our grains

and to show how this can be controlled. We did not enter into a study of the flinty and mealy berries themselves, in fact, we gave no analytical data, but confined ourselves to the direct results of field experiments, using one-tenth-acre plots. These results showed that the percentage of flinty berries was materially increased, practically to the complete elimination of the mealy berries, by the application of nitrogen in the form of nitrate. Further, that the application of potassium increased the percentage of mealy kernels, and gave to all of the kernels a less desirable appearance than the wheats produced on the check plots. I could not convince myself that phosphorus had any perceptible influence on this condition. The only analytical data given in this bulletin pertained to the main features of the soil and sub-soil in regard to the supply of plant food.

The positive and conclusive character of the proof adduced to show the cause of these characters in wheat kernels seemed to render any discussion of the chemical properties of the kernels themselves entirely unnecessary and only a few explanations, for the most part physical, were considered.

At the time I wrote Bulletin 205, I knew of but few observations similar to those I had made. The principal ones were the observations of H. von Feilitzen (Abs. Expt. Sta. Record, Vol. XVII, p. 24), F. Moertlbauer (Abs. Expt. Sta. Record, Vol. XXV, p. 33) and a private communication from Prof. A. Keyser. Quite recently, a year subsequent to the publication of Bulletin 205, I found an article published by Ritthausen and Dr. R. Pott in *Die Landwirthschaftlichen Versuchs Stationen*, Vol. XVI, 1873, pp. 384-399, in which identical conclusions are given, except in regard to the effects of potassium, namely, that nitrates produce small, flinty, hard kernels; and that phosphorus is without effect upon the flintiness or mealiness of the kernels. The two series of experiments are identical in plan and results, in so far as the experiments are co-extensive. I would gladly have cited these experiments made at Poppelsdorf in 1872, had I known of them at the time that I wrote Bulletin 205, as the results obtained under the conditions obtaining in the lower Rhine district in 1872 are identical with those obtained at Fort Collins in 1913 and 1914. Their observations on the effect of nitrates upon the wheat kernels, in comparison with other fertilizer, are of sufficient interest to justify their quotation in this place. These observations are:

“The variety used for seed was one which had been cultivated for a long time at Poppelsdorf. The kernels were flinty, hard and dark colored; kernels of any other character could not be found even on examining a larger quantity.

"The grain from the unmanured plots Nos. 1, 7, and 12 were mostly half-mealy or transitional, light colored, large and plump with smooth and lustrous surface; even the flinty kernels showed this latter characteristic.

"The grain from plots Nos. 4, 8, and 11 manured with superphosphate and phosphoric acid showed exactly the same characteristics, but varied more in size; the number of small, mostly flinty (glassy) kernels was apparently equal to that of the large ones.

"The nitrogenous fertilizers,* Nos. 2, 5, and 9 produced only small, but well-formed, thoroughly hard; flinty and dark colored kernels.

"The kernels obtained from the mixed manuring, Nos. 3, 6 and 10, were like those in the case of pure nitrogenous manuring, all small, hard, flinty and dark, together with no small number of shrunken and imperfectly formed kernels."

Ritthausen and Dr. R. Pott give the nitrogen contained in these grains; the maximum for the check plots was 2.78 percent, that for the phosphoric acid plots was 2.77, that for the nitrogenous manure 3.48, and that for the mixed manuring was 3.82 percent. The moisture in the samples was practically the same, the maximum variation in 12 samples given being about 0.8 percent.

FLINTY KERNELS HIGHER IN NITROGEN

It is not specifically stated in the article that the flinty kernels are higher in nitrogen than the mealy ones, but it evidently can be inferred that this is so. This, however, is generally stated to be a fact. Schindler has been quoted on a previous page as stating "This is also the case even when the flinty and starchy kernels are of the same variety and have been produced in the same field.... P. Holdefleiss found that in one and the same crop of early Bastardweizen the flinty kernels contained 1.957 percent of nitrogen (12.23 percent protein), the mealy ones on the contrary 1.566 percent nitrogen (9.79 percent protein)". The difference in the nitrogen content of flinty and starchy kernels is so thoroughly well established that it is almost, if not altogether, common knowledge. It is also quite as well known that the nitrogen content of the grain can be increased by the application of sodic nitrate or ammonium sulfate. We have so far, then, the following facts pertaining to the effects of nitrogen in the form of nitrates or an easily nitrifiable form of nitrogen; it affects the size of the kernel, tending to produce a small or even shrunken Grain;† it produces a high degree of flintiness and with this a dark,

* The nitrogenous fertilizers used were sodic nitrate and ammonic sulfate.

† A similar observation is made in regard to the effect of nitrates in producing shrunken kernels in Ohio Bul. 243, p. 587, and illustrated on p. 572, showing 60 percent of shriveled kernels.

vitreous appearance, and a higher content of nitrogen. Further, we have the fact that kernels of this character are produced in the same variety of wheat, in the same field and during the same season alongside of large, plump, mealy, light-colored, soft kernels, sometimes even much lower in their nitrogen content. It would seem evident that these results cannot be the result of any climatic conditions, even if we narrow this term down to those accidental features which constitute weather conditions. We can support this view with data of our own collecting. On the other hand, we have our direct observations that potassium increased the percentage of yellow-berry, the size of the kernel, its plumpness, and imparts to it a lighter color. In the summary of Bulletin 243 of Ohio we find this conclusion: "Potassium has increased the proportion of plump kernels, although the yield is the same as when nitrogen is applied to the soil and the composition is practically the same as that found in the wheat from unfertilized soil."* I have a few samples of Ohio wheats, which fact I owe to the courtesy of the Ohio Station, and these samples are so different from our wheats that comparisons are scarcely permissible. But one thing is very striking and this is that they are strongly affected with yellow-berry, or starchiness, and are not comparable with ours in plumpness. I take it that this enhances their observation relative to the effects of potassium upon this characteristic of the kernel. As I am almost wholly ignorant of the conditions under which these samples were grown, I would not, if I desired to do so, permit myself to judge of the causes of the characteristics of these samples further than the author has done.

THE DIFFERENCE IN COMPOSITION OF FLINTY AND STARCHY KERNELS

The physical differences between the flinty and starchy berries are very evident to the eye, much more so than can be expressed in words. We have stated that such berries differ in composition. The annotations in the tables, giving the composition of general samples, are intended to suggest an idea of the composition of yellow-berry wheat, and the table given herewith is intended to show the differences in the composition of these berries grown on our own plots under identical conditions of climate, including the water supply and known conditions of manuring, the soil being as nearly identical as can be obtained. The table contains no samples grown with the application of nitrogen, because these samples contained no mealy kernels. Analyses of such samples will be found in subsequent tables and may also be found in the tables of general samples of winter-wheats for 1914.

* Ohio Bulletin 243, p. 587.

COLORADO EXPERIMENT STATION

ANALYSES OF YELLOW-BERRY AND FLINTY KERNELS GROWN UNDER IDENTICAL CONDITIONS

Variety	Fertilizer Per Acre	Mois- ture	Ash	Fat	Fiber	Nitro- gen	Pro- tein	Starch	Su- crose	Wet Gluten	Dry Gluten	True Gluten
Red Fife, 60 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.568	8.928	66.042	1.108	18.38	7.91	5.748
	Flinty .....	.....	.....	.....	.....	1.881	10.720	61.110	1.034	22.66	9.85	7.032
Red Fife, 40 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.469	8.374	65.286	1.012	17.75	7.77	5.538
	Flinty .....	.....	.....	.....	.....	1.772	10.100	62.712	0.995	21.98	9.55	6.685
Red Fife, 20 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.525	8.692	64.665	1.081	18.05	7.75	5.535
	Flinty .....	.....	.....	.....	.....	1.712	9.756	63.904	1.029	21.78	9.22	6.486
Red Fife, 200 lbs. potassium,	Yellow-berry	8.410	.....	2.105	3.125	1.640	9.348	65.826	1.425	19.23	8.21	5.937
	Flinty	8.348	.....	1.960	3.020	1.949	11.105	61.505	1.449	24.97	10.37	7.497
Red Fife, 150 lbs. potassium,	Yellow-berry	9.310	.....	2.008	2.920	1.600	9.117	65.952	1.016	19.23	8.21	5.914
	Flinty	9.365	.....	1.853	2.912	1.891	10.776	63.378	1.046	23.68	10.10	7.385
Red Fife, 100 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.658	9.448	64.764	1.046	19.92	8.57	6.209
	Flinty .....	.....	.....	.....	.....	1.894	10.796	64.188	1.034	26.00	10.48	7.579
Kubanka, 60 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.583	9.023	63.468	1.260	18.85	8.31	5.867
	Flinty .....	.....	.....	.....	.....	1.811	10.320	62.640	1.232	24.42	10.48	7.290
Kubanka, 40 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.514	8.627	65.547	1.289	19.72	8.62	5.947
	Flinty .....	.....	.....	.....	.....	1.778	10.131	62.766	1.255	24.38	10.34	7.321
Kubanka, 20 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.598	9.105	63.918	1.386	21.32	9.16	6.366
	Flinty .....	.....	.....	.....	.....	1.884	10.739	60.390	1.438	26.97	11.45	8.054
Kubanka, 200 lbs. potassium,	Yellow-berry	8.923	.....	2.113	2.995	1.564	8.910	65.502	1.278	21.47	9.24	6.398
	Flinty	9.068	.....	1.923	2.907	2.044	11.648	62.186	1.260	27.73	11.86	8.380
Kubanka, 150 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.629	9.279	65.070	1.409	22.40	9.65	6.653
	Flinty .....	.....	.....	.....	.....	2.057	11.725	63.792	1.467	28.60	12.25	8.697
Kubanka, 100 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.628	9.279	64.641	1.415	21.85	9.33	6.368
	Flinty .....	.....	.....	.....	.....	2.000	11.400	62.120	1.432	27.30	11.88	8.455
Kubanka, None	Yellow-berry	.....	.....	.....	.....	1.587	9.046	65.848	1.210	21.23	9.31	6.448
	Flinty .....	.....	.....	.....	.....	1.921	10.947	61.812	1.278	27.53	11.87	8.425
Kubanka, None	Yellow-berry	.....	.....	.....	.....	1.599	9.111	62.820	1.560	19.97	8.79	6.160
	Flinty .....	.....	.....	.....	.....	1.969	11.223	62.118	1.432	27.52	11.88	8.423
Kubanka, None	Yellow-berry	9.113	.....	2.230	3.010	1.610	9.174	63.918	1.259	20.57	9.28	6.373
	Flinty	9.430	.....	2.010	2.835	1.936	11.092	62.172	1.369	26.33	11.58	8.193

Fertilizer		DISTRIBUTION OF NITROGEN PERCENTAGE IN YELLOW-BERRY AND FLINTY WHEAT									
Variety	Per Acre	Amid		Albumin		Gliadin		Glutenin		Total	
		Nitrogen		Nitrogen		Nitrogen		Nitrogen		Nitrogen	
Red Fife, 200 lbs. potassium,	Yellow-berry.....	0.0523		0.2028		0.6561		0.7288		1.6400	
	Flinty	0.0523		0.2028		0.7166		0.9768		1.9485	
Red Fife, 100 lbs. potassium,	Yellow-berry.....	0.0488		0.1888		0.6409		0.7210		1.5995	
	Flinty	0.0488		0.1958		0.7667		0.8792		1.8905	
Kubanka, 200 lbs. potassium,	Yellow-berry.....	0.0453		0.1958		0.7096		0.6128		1.5635	
	Flinty	0.0523		0.2098		0.7260		1.0554		2.0435	
Kubanka, no fertilizer	Yellow-berry.....	0.0349		0.1818		0.6921		0.7007		1.6095	
	Flinty	0.0663		0.2168		0.8424		0.8105		1.9360	

*In the case of the Red Fife, the kernels were so generally affected by the yellow-berry that it was almost impossible to sort out a sample of flinty berries which were even for the most part entirely free from the affection, so that, in the end, it was not a question of flinty and yellow-berry kernels, but of very badly and of very slightly affected kernels selected from the same sample of wheat.

ASH CONSTITUENTS OF YELLOW-BERRY AND FLINTY WHEAT

Variety, Kubanka.....	Yellow-berry	Flinty	Flinty
Fertilizer, per acre....	150 lbs. Potassium	100 lbs. Potassium	120 lbs. Nitrogen
	Percent	Percent	Percent
Silica, SiO ₂	0.008	0.022	0.012
Iron, Fe	0.003	0.004	0.004
Manganèse, Mn	0.003	0.004	0.005
Calcium, Ca	0.032	0.032	0.032
Magnesium, Mg	0.140	0.140	0.133
Potassium, K	0.444	0.408	0.418
Sodium, Na	0.041	0.022	0.016
Chlorin, Cl	0.123	0.118	0.093
Sulfur, S.....	0.093	0.103	0.128
Phosphorus, P (total).....	0.394	0.394	0.343
Inorganic, P	0.011	0.011	0.008
Organic, P	0.383	0.383	0.335
Nitrogen, N	1.629	2.057	2.168
Specific Gravity	1.3976	1.4363	1.4241

The above results are given in percentages of the air-dried grain.

THE RATIO OF PROTEIN TO STARCH

As the protein and starch make up about 75 percent of the air-dried wheat, they must bear an inverse relation to one another, i.e., if the percentage of protein is higher it must be largely at the expense of the percentage of the starch. We find that this is, in a measure, true of our results, but it is not so great or regular as we would expect. We see that the total nitrogen is higher in the flinty berries; and this fact persists throughout the analyses for all the forms of nitrogenous substances determined. It is rather surprising that this is shown in the case of the Red Fife samples, for, as the footnote states, the distinction between flinty and starchy kernels in this case was difficult to make. The Kubanka was more easily sorted into two distinct classes. In the case of the check samples, we find that there is a difference of roughly, 0.32 percent of nitrogen in favor of the flinty berries; in the case of the samples grown with phosphorus 0.26 percent; and in the case of the samples grown with the application of potassium, 0.45 percent. We find for the true gluten a difference of 1.4 percent in favor of the flinty kernels in the case of phosphorus fertilization; 2.0 percent with potassium, and 2.0 percent in the case of the check plots. This is not the place to consider the character of the gluten, but it may be stated in a tentative and general way that this feature of the wheat is in favor of the starchy kernels. The glutenin-nitrogen is regularly higher in the flinty kernels.

The total ash is not given in the table, only the mineral, or ash-constituents in the air-dried grain. There are some differences suggested by the results given; the principal one is that the starchy wheats are higher in potassium than the flinty ones.

THE EFFECT OF IRRIGATION ON MEALINESS

Le Clerc attributes mealiness or starchiness in some instances, at least, to irrigation. He says: "It is almost always the case that irrigation tends to produce a mealy grain, although in several instances it has been noted that even under irrigation the grain has kept its flinty character. This is explainable only on the theory that the irrigation has not been excessive."*

Irrigation Had No Effect On Mealiness In Our Experiments

I do not think that this thesis can be maintained, for I have samples of dry-land wheat, winter-wheat of course, in which mealy berries are predominant, constituting 85 percent of the sample. Further, I have samples grown with the same amount of irrigation, which differ greatly in the proportion of mealy kernels present, from less than 20 to nearly 100 percent. The amount of water received during the whole life period of the plants was the same, in one year 21 and in another 19 inches, these are certainly not excessive quantities of water, especially if received as water of irrigation. Further, I have grown wheat with 19 and 31 inches, four plots in each of two successive years. The total supply of 31 inches was at least 12 inches in excess of that required to produce a maximum crop. This excessive amount was applied on 12 July, shortly after the grain had set, and at a very great risk to the crop, for had we had a slight shower accompanied by wind, the grain would have gone down and been severely injured. The effect of this irrigation on the development of yellow-berry, or mealiness of the kernels was nil. If there be any difference in the samples of the different varieties treated in this manner, it is in favor of the heavier irrigation. These samples have been analyzed, and there are no differences that can be attributed to the difference in the amount of irrigating water applied. The four plots used in this case were checks, and had received no fertilizer, so they are thoroughly comparable with the other checks.

Through the kindness of Mr. Don. H. Bark, now with the Canadian Pacific Railroad, but formerly with the U. S. Department of Agriculture, I received a set of six samples grown under controlled conditions in regard to water applied and fertilization. The variety is Marquis. I will not give the analyses in this place, but simply state that the water applied to six one-tenth-acre plots varied from the rate of 1 to 3 feet per acre. The time from planting till harvest was 122 days; the time from the first till the last irrigation was 102 days, during which two of the six plots received 12 inches of water, two 24 inches, and two 36 inches each per acre. So far as the mealiness of these

* Yearbook U. S. D. A., 1906, p. 205.

samples is concerned, no differences are to be noted. Fortunately for our present purposes they are badly affected by yellow-berry and, apparently, equally so. It is scarcely possible that 1 foot of water applied in three applications distributed over 102 days was materially more than a necessary quantity, and yet the mealy berries are just as abundant in this wheat as in that that received 3 feet of water.

It may be well for me to state that in my own experiments I could not see that the second irrigation, applied on 12 July about 30 days before harvest, did either good or harm; it appeared to be entirely indifferent so far as my crop was concerned, and was worse than useless, because, I thereby exposed my crop to unnecessary risks of damage by wind. The growth of the plants was already luxuriant, and had only a slight shower, accompanied by wind, occurred while the ground was as soft as a foot of water could make it, all manner of evils would have followed.

There is another very important feature connected with the samples Mr. Bark furnished me, i.e., three of the plots had received a heavy dressing of farmyard manure, sixteen loads to the acre, but I could not see that this had changed the character of the wheat. It increased both the amount of straw and grain, but had very little or no effect upon the character of the grain.

Irrigating Water and Rainfall May Have Entirely Different Effects

So far as mealiness and flintiness of the berries are concerned, the amount of water applied, up to 3 feet in 102 days, is without effect. I will digress to anticipate the discussion of our 1915 results to the extent of stating that *water applied to the ground in irrigation and water applied to the plant in the form of frequent light rains produce altogether different results*. Our crops in 1913 and 1915 are very different though they were grown with the same fertilization and the same amount of water, 19 inches in each case. In the former year we applied 12 inches of water and had 7 inches of rainfall, in the latter year, we applied 6 inches of water and had 13 inches of rainfall. The results are interesting, as we shall see when we come to discuss them, but so far as the question at present under consideration is concerned, they were practically without effect, which sustains my contention that these characteristics of the wheat kernel are dependent neither upon the weather nor the water applied, but upon the soil.

We have now, in addition to the facts adduced in Bulletin 205, the facts that berries grown on the same ground, under the same conditions of weather, differ in physical and chemical properties. Neither the weather nor water supply can be appealed to to account for this difference; wheat grown as dry-land wheat may be as badly affected by

mealiness as wheat grown with irrigation. Water applied to the soil up to 3 acre-feet in 102 days does not produce mealiness to any greater extent than 1 acre-foot, or than may occur in dry-land wheat. It is shown, further, that when the water is applied to the plant in a succession of light rains very marked effects may be produced upon the composition of the plant and the grain, but the question of flintiness and mealiness, and the characteristics of such kernels, remain unaffected.

MEALINESS CAUSED BY TOO HIGH A RATIO OF POTASSIUM TO AVAILABLE NITROGEN

It was stated in Bulletin 205 that the cause of mealiness was an unfavorable ratio of potassium to available nitrogen, which, for the wheat plant, is equivalent to nitric-nitrogen. By unfavorable ratio of potassium in this case is meant one which is too high. Just what too high a one is we have not determined, but in our soil the application of 40 pounds of nitrogen in the form of sodic nitrate at the time of seeding spring-wheat is sufficient to change the product from a light colored one, in which plump, mealy berries, low in nitrogen are abundant, to one in which the berries are smaller, possibly shrunken, flinty, translucent, and richer in nitrogen. How much washing with irrigating water it may take to remove this nitrate beyond the reach of the plant and prevent its production of flinty grains has not been determined. Two feet of water, one applied on 12 June the other on 12 July, plus 7 inches of rainfall during the season, will not suffice to do it, nor will 6 inches of irrigating water plus 13 inches of rainfall prevent its producing flinty berries, even when no lodging takes place. Further, it has not been determined how small a quantity of nitrogen applied in this form may produce this effect, nor has it been determined at what period in the development of the plant its application will produce the most favorable result. We have demonstrated that application of nitrates made four weeks later still affect the growth of the plant, and further, that 80 pounds of nitrogen applied in two equal dressings four weeks apart will almost certainly do injury by lodging the straw, shrivelling the wheat, and inducing an attack of rust.

In Parts I and II of this study we have given much attention to the moisture, and also to the nitrates in the soil, their distribution, and the rate of their formation, because of their importance in this connection.

There is another view of the yellow-berry subject which connects it still more intimately with our experiments. This is the question whether the composition of flinty berries, such as is produced by the application of nitrogen as sodic nitrate, is desirable or not, which we will consider after we have given further data pertaining to our crops.

THE CRUSHING STRENGTH OF WHEAT

After explaining that flinty and mealy wheats differ in their structure, in that the mealy kernels contain air-filled spaces which reflect the light and cause the berries to appear white and opaque, and that the flinty berries, owing to the absence of such air-filled spaces, permit the passage of the light and therefore appear translucent or flinty, Schindler says that the flinty berries are designated as hard wheats and the mealy ones as soft wheats.* This is the clearest definition of these terms that I have met with, but they are not generally used with the sharp distinction of this definition. Attempts have been made to determine the degrees of hardness of different wheats and use the figures obtained as a means of classification. At the California Station they determined the weight necessary to cut the kernels when they were placed between the jaws of a pair of pinchers.† At the Kansas Station they used a "Grain Tester" devised in conjunction with Wm. Gaertner & Co., of Chicago, in which they determined the weight necessary to crush the kernels when placed under a steel pestle in a miniature mortar.‡ On page 374 of Kansas Bulletin 167, Prof. Roberts gives the following basis of classification. "In general we find that 'soft' wheats crush under a pressure of 6,000 grams or less (13 pounds), semi-hard wheats at about 9,000 grams (20 pounds) and hard wheats at 12,000 grams and over (26 pounds and over).

OUR METHOD OF DRYING

Prof. Roberts dried his samples for seven days at the boiling point of water under ordinary atmospheric pressure and preserved them in a desiccator till used. I dried our samples at 100° C., under a pressure of 75 mm. for 7 hours, corked the bottles tightly and preserved them in a desiccator. The object in this drying is to bring all of the samples to a common basis in regard to moisture, but it is a question whether there is any need of doing this, for the variation in moisture at a given locality is not great and this factor adjusts itself if wheat is transported from one place to another, and the tests are all made at the place of grading. There seems to be a more serious question raised by drying than the variation due to the moisture in the wheat, i.e., does drying at 100° C., for seven days leave the wheats in such a condition that the determination gives us the real crushing strength of the sample, or only that which it may chance to show under a purely artificial condition? Even this would not be a serious objection if we could be sure that all samples deported themselves in a similar

* Schindler, *Der Getreidebau*, 1909, p. 151.

† California Bul. 212, G. W. Shaw and A. J. Gaumnitz, p. 335.

‡ Kansas Bul. 167, H. F. Roberts, "A Quantitative Method for the Determination of Hardness in Wheat."

manner under this treatment, for then, we could determine how much the crushing strength was decreased or increased by the drying and could make the proper addition or subtraction as necessary if deemed advisable. We have taken 36 groups of 350 kernels each, in all 12,600 kernels. Eighteen sets were dried as stated and 18 others were used in their air-dried condition. Air-dried, in our case, indicates about 10.0 percent of moisture in the wheat. The results are given in the following tabular statement:

CRUSHING STRENGTH OF SOME COLORADO WHEATS

	Air-dried Oven-dried	
Red Fife, received no irrigation.....	.....	8.258
Defiance, received no irrigation.....	9.112	12.256
Harvest King, Grand Junction.....	.....	7.420
Defiance, J. B. Hunter.....	.....	7.496
Defiance, Red Cross Ranch, Clifton.....	.....	11.386
Red Cross Winter Wheat, Fruita.....	.....	7.188
Minnesota Spring No. 1.....	.....	9.548
Minnesota Spring No. 2.....	.....	9.094
Defiance, Agricultural College, Ft. Collins.....	.....	12.367
Red Fife, Agricultural College, Ft. Collins.....	.....	9.905
Marquis, Agricultural College, Ft. Collins.....	.....	10.464
Red Fife, South Dakota Experiment Station....	.....	7.909
Kubanka, South Dakota Experiment Station.....	.....	16.569
Defiance, Sect. 1800, 80 lbs. of nitrogen.....	10.087	10.623
Defiance, Sect. 1800, 40 lbs. of phosphorus.....	10.938	11.860
Defiance, Sect. 1800, 150 lbs. of potassium.....	11.042	12.759
Defiance, Sect. 1800, no fertilizer.....	11.190	12.048
Red Fife, Sect. 1800, 80 lbs. of nitrogen.....	11.212	10.263
Repeated	10.653	10.476
Red Fife, Sect. 1800, 40 lbs. of phosphorus.....	10.711	9.898
Repeated	10.235	10.184
Red Fife, Sect. 1800, 150 lbs. of potassium.....	10.678	9.946
Repeated	10.365	10.043
Red Fife, Sect. 1800, no fertilizer.....	10.971	10.082
Repeated	10.314	10.422
Kubanka, Sect. 1800, 80 lbs. of nitrogen.....	15.839	19.111
Kubanka, Sect. 1800, 40 lbs. of phosphorus.....	15.505	18.517
Kubanka, Sect. 1800, 150 lbs. of potassium.....	15.495	17.225
Kubanka, Sect. 1800, no fertilizer.....	15.354	19.122
Defiance, Sect. 1900, 100 lbs. of potassium, yellow-berry..	8.213	9.197
Defiance, Sect. 1900, 100 lbs. of potassium, flinty.....	10.351	13.644
Kubanka, Sect. 1800, 150 lbs. of potassium, yellow-berry..	.....	13.056
Kubanka, Sect. 1800, 150 lbs. of potassium, flinty.....	.....	18.234
Red Fife, Sect. 1800, 150 lbs. of potassium, yellow-berry..	.....	7.734
Red Fife, Sect. 1800, 150 lbs. of potassium, flinty.....	.....	9.469

COLORADO WHEATS ARE SEMI-HARD TO HARD

According to the results obtained and adopting the suggested standard of classification, our wheats are semi-hard to hard. The Minnesota samples would be classed as semi-hard, while our Defiance would be classified as a hard wheat. My understanding of the situation is that our Defiance is classed by the millers as a soft wheat, and while

the flour made from it is white and very pleasing to the eye, it is not a good bread-making flour, as it only makes from 250 to 260 loaves to the barrel.

In the case of the Defiance and also of the Kubanka, we find that drying as described, causes an increase of from 1,000 to about 3,000 grams in the crushing strength of the kernels, but in the case of the Red Fife, we find that drying has lowered the crushing strength. Of course, we base all statements on the assumption that 350 kernels, taken without choice, is sufficient to give us a close approximation to the average crushing strength of the samples. This number is adopted from the Kansas bulletin. We were surprised in the first place that the Red Fife should show a lower crushing strength than the Defiance, in the second place that its crushing strength should be lowered by the drying instead of raised, as in case of the other two varieties. It will be noticed that the whole series of experiments with the Red Fife was repeated, and that the second series corroborated the results of the first.

Further, these two series agree as closely as we have any right to expect them to agree. Feeling that I might be prejudiced in my results, i.e., the discrepancy between my results and the public estimate of the wheats experimented with, I requested a friend who is proficient in this kind of calculation to analyze the data given in the Kansas bulletin and see how closely their groups would agree; the results were more disconcerting to me than my own figures, and I am inclined to allow a variation of plus or minus 300 grams or more for single groups of 350 each. They, of course, may come much closer if the wheat is very uniform, which is seldom the case, as is evident on the most casual observation of our mixed wheats. The variation which may be found in individual samples, due to the flintiness or mealiness of the kernels, is indicated by the last six samples given in the second column of the table, or eight including the last two samples in the first column. This group of samples is given to show the difference in the crushing strength of flinty and mealy or yellow-berry kernels selected from the same sample, and consequently grown on the same soil under the same conditions of cultivation and climate. This difference for Defiance, dried at 100° C., is, in round numbers, 4,500, and in the air-dried condition 2,100 grams, and for the Kubanka, dried at 100° C., 5,200 grams. The difference shown by the table between the flinty and mealy kernels in the Red Fife sample, 1,700 grams, is altogether as significant as the greater differences found for the other varieties, because the sample grown with the application of 150 pounds of potassium was so badly affected by this condition that the selection of a flinty sample was exceedingly difficult, and the separation was

only partially successful. One must acknowledge, however, that no one of the 21 samples of this variety tested showed more than a medium degree of hardness, according to this test. The maximum crushing strength, 11,212 grams, is found in the air-dried sample grown with the application of 80 pounds of nitrogen. This sample is to all appearances an unexceptional one.

PLANT'S NOURISHMENT INFLUENCES CRUSHING STRENGTH

Whether the result of classification by this method corresponds to the milling or flour-making qualities of the wheat or not, it serves to show according to the table given, that the plant's nourishment actually influences the crushing strength of the average kernel, and that yellow-berries are more easily crushed than the flinty ones. This is a conclusion at which one arrives with just as satisfactory a degree of certainty by crushing the berries between his teeth, but this method gives no measure of the difference. The differences in the cases given in the table, vary, from 1,400 to 5,000 grams, in favor of the flinty berries, and if a variation of 200 or even 300 grams from the true average exists, it scarcely lessens the value of the result, for it is only an approximation to the true average.

The results obtained with the Defiance samples, would seem to contradict all that we have affirmed concerning the effects of nitrates upon this feature of the kernels. An examination of the samples, however, suggests a ready explanation for the results. The sample grown with the application of potassium, consists of light-colored, plump kernels with a very low percentage of mealiness, while that grown with the application of nitrogen, consists of dark-colored, small, and to a large extent, badly shrunken kernels, so that the results given by the testing machine are just what one would expect from a simple examination of the samples. Had we picked out the shrunken kernels from the sample grown with nitrogen, or even sifted out the small kernels, and compared kernels of equal size we, undoubtedly, would have had a very different result. Such a procedure was, of course, not to be thought of; it would, however, have given us results for kernels more nearly normal and equal in size. How significant this factor is, may be inferred from the fact that the crushing strength of the individual kernels in the case of the nitrate sample varies from 5,000 to 17,000 grams. The difference in the size of the kernels is indicated by the weight for 1,000 kernels. The wheat grown with nitrate weighed 31.5 grams and that grown with potassium weighed 38.77, a difference of 23.0 percent. There was more difference than is suggested by these weights, for the wheat grown with the application of nitrogen is shrunken while that grown under other conditions is full and round;

this difference in form must certainly make a big difference in the crushing strength of the kernels, in whatever position they may be placed under the pestle. We placed every kernel in the same position, namely, crease downward. I do not think that there is any result obtainable by this method of investigation which is definite enough to advance the object of our investigation.

THE WHEATS GROWN AND CULTURAL METHODS USED

In the experiments planned to ascertain something definite concerning the part played by individual factors in determining the character of our wheat we have used three varieties. Defiance, a wheat of local origin, which has retained public favor in this State, for upwards of thirty years, Red Fife and Kubanka. I chose spring-wheat, because, until recently, almost no winter-wheat was grown in the State, further, because, its whole growing period, from planting till maturity, is short and without any resting period, or one principally of underground development, and also because we escape the danger of winter-killing. We grew twelve plots of each variety, three plots were dressed with sodic nitrate, three with rock superphosphate, three with potassic chlorid and three were used as check plots. This gives us 36 plots in all. The experiments with the different varieties were the same, so that the statement of them for one variety will suffice for the others.

In 1913, Sections 1700 and 1800 were plowed with a turning plow to a depth of 12 inches and with a subsoil plow to a depth of 16 inches, or 4 inches deeper than the turning plow. Section 1900 was turned to a depth of nine inches and not subsoiled. The deep cultivation was given, because the average depth to which it had previously been stirred was not more than 6 or 7 inches. The deep stirring was in some respects a mistake, but this has been discussed elsewhere and as no very serious results followed, it need not be discussed at this time. The fertilizers were applied as follows: Nitrogen at the rate of 120 pounds per acre to the plots receiving this fertilizer in Section 1700, 80 pounds to those in Section 1800 and 40 pounds to those in Section 1900. Phosphorus, at the rate of 60 pounds of soluble phosphorus to the acre, to the plots receiving this manure in Section 1700, 40 pounds to those in Section 1800, and 20 pounds to those in Section 1900. Potassium at the rate of 200 pounds per acre to those plots receiving it in Section 1700, 150 pounds per acre to those in Section 1800, and 100 pounds to those in Section 1900. There was a check plot in each section of land for each variety. It will be noticed that the plots in Section 1900 received the minimum amount. We have adhered to this order throughout the three seasons. The whole amount of phosphorus and potassium was applied at the time of planting and was harrowed in.

An application of 40 pounds of nitrogen was made to all of the plots that were treated to this manure at planting time and harrowed in just as the other fertilizers. But the plots receiving larger quantities received subsequent applications; those plots in Section 1800 another application of 40 pounds, and those in Section 1700 two other applications of this amount, 120 pounds in all. The applications of nitrogen, as sodic nitrate, were made at intervals of about four weeks. All plots received an irrigation 12-16 June and four plots received a second irrigation four weeks later, 11-13 July, in 1913 and 1914, but not in 1915, because the frequent light rains of this season kept the plants loaded with water. The characteristics of the weather, especially for 1913 and 1915, have been stated, as also have the general crop-data, yield per acre, weight per bushel, and the ratio of straw to grains. An examination of the figures giving this latter ratio will show that it is very abnormally high for the Defiance in 1914, and for all varieties in 1915. There were two causes operative in 1915 tending to bring this about. One of these causes was the presence of an unusually large amount of wild oats which increased the weight of the straw and for which no adequate compensation was made in the weight of the grain. This cause had nothing to do with this ratio for the Defiance in 1914.

RUST INCREASED RATIO OF STRAW TO GRAIN

While the following statements may not belong in this place, their misplacement may emphasize the explanation offered for the appearance of the wild oats, namely, that we distributed them over the land with the water that was applied the preceding autumn preparatory to cultivating it. This water simply washed out the ditches in which these wild oats had collected and distributed them on our land. The other cause alluded to, acted in a more direct and effective manner in increasing the ratio of straw to grain. This cause was the rust that developed on the plants. This parasite practically killed the Defiance wheat grown with the application of nitrogen in both 1914 and 1915. The grain produced in these plots could scarcely be called grain at all, and such as we got weighed as low as 52 pounds per bushel in 1914, and 47 pounds in 1915. The yield being low—it fell to less than 9 bushels in 1915—and the weight light, the ratio of straw to grain must necessarily be high. That this was wholly due to rust in 1914, and almost wholly so in 1915, there can be no doubt. The wild oats may be mixed with the wheat and increase the weight of the straw, but do not cause shrunken, light-weight grains, which is a characteristic effect of rust.

I have tried to show that we have but little justification in thinking that we can arrive at any certainty in regard to the real character-

istics of our wheats by a study of general samples, because we have in them too great a variety of properties, and the effects of too many conditions, in part or wholly unknown to us. The big features of the climatic conditions have been asserted, but are not so well known that we can state exactly in what these consist. The influence of the soil-factors has been recognized in a general way, but has been considered small in comparison with climatic influences. Here again, neither the kind of effects, nor their extent have been made out. It may be, and probably is the fact, that the wheat plant is very susceptible to very slight changes in the balance of its nutritive solutions, and at the same time very sensitive, especially at certain periods in its development, to unfavorable climatic influences. Further, it is evidently very sensitive to the injury inflicted by some parasites, rust for instance. There may be differences in varieties in these respects, but there is no occasion for making modifications in these general statements, as they, in the main, seem to be correct.

COMPOSITION OF WHEATS GROWN IN 1913

The following tables present the composition of the wheats grown on our plots during the season of 1913, given by section and variety:

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	Nitrogen 120 lbs.....	11.825	1.921	1.598	2.362	2.630	14.989	59.788	1.142	35.37	13.98	10.340	0.442	0.440	33.50
Defiance,	Phosphorus 60 lbs.....	11.393	1.917	1.728	2.625	2.113	12.042	61.632	1.232	25.66	10.27	7.336	0.447	0.444	37.54
Defiance,	Potassium 200 lbs.....	11.493	1.930	1.725	2.505	2.012	11.469	61.236	1.255	23.40	9.53	6.736	0.447	0.425	38.19
Defiance,	None	11.455	1.943	1.605	2.603	2.016	11.492	62.154	1.249	24.33	9.99	7.067	0.452	0.436	37.03
Red Fife,	Nitrogen 120 lbs.....	10.408	1.823	1.815	2.630	2.665	15.188	60.192	1.249	36.07	13.83	10.200	0.452	0.488	30.81
Red Fife,	Phosphorus 60 lbs.....	10.390	2.006	1.775	2.642	2.358	13.442	61.308	1.501	26.87	10.92	7.848	0.476	0.502	33.56
Red Fife,	Potassium 200 lbs.....	10.303	1.994	1.808	3.000	2.274	12.961	62.910	1.467	28.40	11.23	8.151	0.475	0.442	33.53
Red Fife,	None	10.910	2.053	1.778	2.708	2.270	12.936	62.338	1.289	27.10	11.06	7.990	0.449	0.453	33.75
Kubanka,	Nitrogen 120 lbs.....	11.410	1.869	2.078	2.382	2.528	14.411	59.310	1.697	32.93	13.49	9.857	0.404	0.482	43.11
Kubanka,	Phosphorus 60 lbs.....	10.783	1.929	2.098	2.740	2.159	12.305	61.504	1.415	26.73	11.16	7.777	0.441	0.497	43.19
Kubanka,	Potassium 200 lbs.....	10.505	1.988	1.843	2.400	2.160	12.311	62.028	1.467	26.47	11.34	7.761	0.431	0.473	42.72
Kubanka,	None	10.288	1.981	1.998	2.455	2.144	12.221	59.670	1.352	27.33	11.29	8.201	0.441	0.445	42.13

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS IN 1913

—SECTION 1700

Variety	Fertilizer per acre	Amid		Albumin		Gliadin		Glutenin		Total	
		Nitrogen Percent	Percent	Nitrogen Percent	Percent	Nitrogen Percent	Percent	Nitrogen Percent	Percent	Nitrogen Percent	Percent
Defiance,	Nitrogen, 120 lbs..	0.0699	0.2168	0.1958	1.1789	1.1623	2.6297	0.9994	2.1126	0.9542	2.0121
Defiance,	Phosphorus, 60 lbs.	0.0418	0.1958	0.1818	0.8756	0.9994	2.1126	0.9542	2.0121	0.9022	2.0161
Defiance,	Potassium, 200 lbs.	0.0523	0.1958	0.1958	0.8238	0.9542	2.0121	0.9022	2.0161	1.3504	2.6645
Defiance,	None	0.0523	0.1958	0.1958	0.8558	0.9022	2.0161	1.3504	2.6645	1.1327	2.3583
Red Fife,	Nitrogen, 120 lbs..	0.1049	0.2237	0.2098	0.9855	1.3504	2.6645	1.1327	2.3583	1.1554	2.2739
Red Fife,	Phosphorus, 60 lbs.	0.1328	0.2098	0.1958	0.8830	1.1327	2.3583	1.1554	2.2739	1.1697	2.2695
Red Fife,	Potassium, 200 lbs.	0.1363	0.1958	0.1678	0.7864	1.1697	2.2695	1.1697	2.2695	1.3766	2.5283
Red Fife,	None	0.1188	0.1678	0.1958	0.8132	1.1697	2.2695	1.3766	2.5283	0.8818	2.1587
Kubanka,	Nitrogen, 120 lbs..	0.0804	0.1958	0.2517	0.8755	1.3766	2.5283	0.8818	2.1587	1.0271	2.1599
Kubanka,	Phosphorus, 60 lbs.	0.0628	0.2517	0.1958	0.9624	1.0271	2.1599	0.8704	2.1599	0.8392	2.1441
Kubanka,	Potassium, 200 lbs.	0.0663	0.1958	0.1958	0.8704	1.0271	2.1599	0.8704	2.1599	0.8392	2.1441
Kubanka,	None	0.0593	0.1958	0.1958	1.0498	0.8392	2.1441	0.8392	2.1441	0.8392	2.1441

WHEATS GROWN ON EXPERIMENTAL PLOTS IN 1913—SECTION 1800

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Straw Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	Nitrogen 80 lbs.....	10.818	1.848	1.728	3.007	2.435	13.788	60.264	1.051	31.33	12.32	9.220	0.393	0.446	32.73
Defiance,	Phosphorus 40 lbs....	10.665	1.903	1.700	2.782	2.107	12.008	62.118	1.125	24.50	9.85	7.038	0.442	0.437	38.76
Defiance,	Potassium 150 lbs....	10.675	1.860	1.705	2.738	2.163	12.330	63.014	1.455	24.50	10.08	7.099	0.408	0.420	39.94
Defiance,	None	11.268	1.695	1.780	2.568	2.130	12.139	61.830	1.352	25.07	10.22	7.313	0.416	0.453	38.84
Red Fife,	Nitrogen 80 lbs.....	9.828	1.928	1.810	2.684	2.616	14.909	60.002	1.329	32.20	12.84	9.487	0.405	0.466	34.36
Red Fife,	Phosphorus 40 lbs....	9.810	2.085	1.783	2.525	2.323	13.242	61.340	1.091	27.00	11.04	8.171	0.458	0.440	34.59
Red Fife,	Potassium 150 lbs....	10.095	2.013	1.918	2.582	2.422	13.806	61.760	1.221	27.20	11.07	8.039	0.459	0.423	35.94
Red Fife,	None	10.633	2.050	1.865	2.755	2.531	14.428	61.882	1.147	28.83	11.55	8.335	0.462	0.410	35.34
Kubanka,	Nitrogen 80 lbs.....	11.780	1.721	1.995	2.830	2.414	13.758	60.894	1.449	30.10	12.30	8.530	0.373	0.423	42.18
Kubanka,	Phosphorus 40 lbs....	11.215	1.877	1.935	2.412	2.090	11.911	61.578	1.519	26.50	11.06	7.815	0.407	0.477	43.56
Kubanka,	Potassium 150 lbs....	11.110	1.875	1.935	2.462	2.111	12.032	62.622	1.392	25.50	10.60	7.316	0.411	0.434	43.76
Kubanka,	None	11.330	1.971	1.800	2.862	2.114	12.048	63.374	1.438	25.33	10.63	7.572	0.423	0.480	45.96

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS 1913—SECTION 1800

Variety	Fertilizer per acre	Amid			Albumin			Gliadin			Glutenin			Total		
		Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent
Defiance,	Nitrogen, 80 lbs...	0.0699	0.1748	0.1748	0.0699	0.1748	0.1748	1.0764	1.1134	1.1134	2.4345	2.4345	2.4345	2.4345	2.4345	2.4345
Defiance,	Phosphorus, 40 lbs.	0.0628	0.1888	0.1888	0.0628	0.1888	0.1888	0.8506	1.0045	1.0045	2.1067	2.1067	2.1067	2.1067	2.1067	2.1067
Defiance,	Potassium, 150 lbs.	0.0558	0.1818	0.1818	0.0558	0.1818	0.1818	0.8716	1.0539	1.0539	2.1631	2.1631	2.1631	2.1631	2.1631	2.1631
Defiance,	None	0.0523	0.1678	0.1678	0.0523	0.1678	0.1678	0.8704	1.0392	1.0392	2.1297	2.1297	2.1297	2.1297	2.1297	2.1297
Red Fife,	Nitrogen, 80 lbs...	0.1049	0.2028	0.2028	0.1049	0.2028	0.2028	0.9855	1.3224	1.3224	2.6156	2.6156	2.6156	2.6156	2.6156	2.6156
Red Fife,	Phosphorus, 40 lbs.	0.0979	0.2028	0.2028	0.0979	0.2028	0.2028	0.8900	1.1324	1.1324	2.3231	2.3231	2.3231	2.3231	2.3231	2.3231
Red Fife,	Potassium, 150 lbs.	0.1014	0.2307	0.2307	0.1014	0.2307	0.2307	0.8771	1.2129	1.2129	2.4221	2.4221	2.4221	2.4221	2.4221	2.4221
Red Fife,	None	0.0944	0.2377	0.2377	0.0944	0.2377	0.2377	0.8982	1.3009	1.3009	2.5312	2.5312	2.5312	2.5312	2.5312	2.5312
Kubanka,	Nitrogen, 80 lbs...	0.0628	0.2168	0.2168	0.0628	0.2168	0.2168	0.9298	1.2043	1.2043	2.4137	2.4137	2.4137	2.4137	2.4137	2.4137
Kubanka,	Phosphorus, 40 lbs.	0.0523	0.2168	0.2168	0.0523	0.2168	0.2168	0.9356	0.8849	0.8849	2.0896	2.0896	2.0896	2.0896	2.0896	2.0896
Kubanka,	Potassium, 150 lbs.	0.0488	0.2237	0.2237	0.0488	0.2237	0.2237	0.7947	1.0437	1.0437	2.1109	2.1109	2.1109	2.1109	2.1109	2.1109
Kubanka,	None	0.0523	0.2237	0.2237	0.0523	0.2237	0.2237	0.8191	1.0186	1.0186	2.1137	2.1137	2.1137	2.1137	2.1137	2.1137

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Strat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	Nitrogen 40 lbs.....	11.763	1.851	1.728	2.532	2.290	13.051	63.486	1.306	24.33	10.13	7.241	0.454	0.476	35.01
Defiance,	Phosphorus 20 lbs....	11.830	1.792	1.820	2.600	1.865	10.631	64.010	1.392	20.17	8.53	5.854	0.456	0.473	35.23
Defiance,	Potassium 100 lbs....	11.565	1.894	1.798	2.528	1.960	11.173	63.400	1.215	23.00	9.57	6.413	0.480	0.476	38.74
Defiance,	None	11.798	1.905	1.775	2.575	2.038	11.615	63.324	1.063	23.50	9.59	6.914	0.480	0.480	36.37
Red Fife,	Nitrogen 40 lbs.....	10.363	1.961	1.803	2.512	2.543	14.493	61.956	1.438	30.07	12.26	8.709	0.479	0.501	33.82
Red Fife,	Phosphorus 20 lbs....	10.653	2.065	1.860	2.600	2.394	13.646	62.334	1.478	28.40	11.67	8.305	0.522	0.496	34.18
Red Fife,	Potassium 100 lbs....	10.278	2.077	1.878	2.617	2.487	14.178	61.812	1.323	27.66	11.16	8.174	0.505	0.444	34.20
Red Fife,	None	10.378	2.060	1.750	2.675	2.470	14.079	63.290	1.352	28.57	11.58	8.305	0.506	0.454	34.22
Kubanka,	Nitrogen 40 lbs.....	11.515	1.822	1.878	2.437	2.261	12.887	61.272	1.656	28.80	11.82	8.407	0.419	0.461	46.82
Kubanka,	Phosphorus 20 lbs....	11.248	1.974	1.960	2.562	2.187	12.464	63.090	1.549	26.66	10.92	7.803	0.444	0.471	46.53
Kubanka,	Potassium 100 lbs....	10.850	1.889	1.748	2.600	2.253	12.843	61.729	1.341	25.57	10.80	7.781	0.432	0.497	45.33
Kubanka,	None	11.200	1.947	1.813	2.522	2.207	12.583	62.046	1.467	25.40	10.79	7.661	0.458	0.494	45.53

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS 1913—SECTION 1900

Variety	Fertilizer per acre	Amid		Albumin		Gliadin		Glutenin		Total	
		Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent
Defiance,	Nitrogen, 40 lbs...	0.0488	0.1958	0.8599	1.1852	2.2897	1.8651	1.9601	2.0377	2.5426	2.8609
Defiance,	Phosphorus, 20 lbs.	0.0453	0.1958	0.7143	0.9097	1.8651	1.9601	2.0377	2.5426	2.8609	2.8609
Defiance,	Potassium, 100 lbs.	0.0384	0.2098	0.7631	0.9449	1.8651	1.9601	2.0377	2.5426	2.8609	2.8609
Defiance,	None	0.0483	0.2028	0.8417	1.2983	2.5426	2.8609	2.8609	2.8609	2.8609	2.8609
Red Fife,	Nitrogen, 40 lbs...	0.0909	0.2098	0.9436	1.1591	2.3940	2.4873	2.4873	2.4873	2.4873	2.4873
Red Fife,	Phosphorus, 20 lbs.	0.0909	0.2517	0.8923	1.1591	2.3940	2.4873	2.4873	2.4873	2.4873	2.4873
Red Fife,	Potassium, 100 lbs.	0.0909	0.2866	0.9203	1.1895	2.4873	2.4873	2.4873	2.4873	2.4873	2.4873
Red Fife,	None	0.0593	0.3006	0.9472	1.1629	2.4700	2.4700	2.4700	2.4700	2.4700	2.4700
Kubanka,	Nitrogen, 40 lbs...	0.0349	0.2726	0.8738	1.0796	2.2609	2.2609	2.2609	2.2609	2.2609	2.2609
Kubanka,	Phosphorus, 20 lbs.	0.0349	0.2447	0.8459	1.0611	2.1866	2.1866	2.1866	2.1866	2.1866	2.1866
Kubanka,	Potassium, 100 lbs.	0.0628	0.2098	0.7527	1.2279	2.2532	2.2532	2.2532	2.2532	2.2532	2.2532
Kubanka,	None	0.0418	0.2377	0.8110	1.1171	2.2076	2.2076	2.2076	2.2076	2.2076	2.2076

MINERAL CONSTITUENTS OF WHEAT GROWN AT FORT COLLINS, CROP OF 1913

Variety	Fertilizer per Acre	Sp. Gr.	SiO ₂ Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Defiance	Nitrogen 80 lbs.	1.4228	0.011	0.004	present	0.043	0.132	0.419	0.023	0.058	0.153	0.393	0.026	0.367	2.435
Defiance	Phosphorus 40 lbs.	1.4311	0.016	0.004	present	0.036	0.146	0.408	0.036	0.052	0.120	0.442	0.029	0.413	2.107
Defiance	Potassium 150 lbs.	1.4355	0.015	0.006	present	0.030	0.136	0.401	0.041	0.058	0.128	0.408	0.023	0.385	2.163
Defiance	None	1.4347	0.030	0.005	present	0.037	0.141	0.391	0.037	0.060	0.116	0.416	0.029	0.387	2.119
Red Fife	Nitrogen 80 lbs.	1.4405	0.044	0.005	present	0.033	0.150	0.438	0.027	0.072	0.120	0.414	0.022	0.392	2.615
Red Fife	Phosphorus 40 lbs.	1.4429	0.013	0.007	present	0.033	0.155	0.439	0.022	0.063	0.115	0.456	0.030	0.426	2.323
Red Fife	Potassium 150 lbs.	1.4468	0.009	0.007	present	0.027	0.152	0.430	0.019	0.093	0.114	0.457	0.026	0.431	2.422
Red Fife	None	1.4401	0.017	0.006	present	0.038	0.153	0.444	0.010	0.135	0.113	0.461	0.029	0.432	2.521
Kubanka	Nitrogen 80 lbs.	1.4400	0.031	0.005	present	0.048	0.133	0.453	0.002	0.117	0.124	0.364	0.014	0.350	2.442
Kubanka	Phosphorus 40 lbs.	1.4354	0.034	0.005	present	0.041	0.141	0.453	0.016	0.134	0.101	0.407	0.016	0.391	2.085
Kubanka	Potassium 150 lbs.	1.4368	0.010	0.004	present	0.035	0.122	0.458	0.011	0.129	0.104	0.411	0.017	0.394	2.111
Kubanka	None	1.4355	0.030	0.005	present	0.031	0.137	0.454	0.010	0.130	0.093	0.423	0.016	0.407	2.114

SEASON OF 1913 VERY FAVORABLE—WHAT OUR EXPERIMENTS SHOWED US

The season of 1913 was very favorable throughout the whole period of growth and ripening. The early spring was quite wet and our planting was late. The period from planting till harvest was 101 days. There was very little rust, so little that we shall consider its effects negligible. A comparison of the nitrogen found in the three samples of each variety grown on the check plots shows that there is a greater variation in them than can be attributed to errors in the determinations; further, that, corresponding to the differences in the check plots, the samples of Defiance and Red Fife are higher on Section 1800 than on the other two sections. In the case of the Kubanka, there is but little difference, especially in samples grown without the application of nitrogen. It shows, further, that there is an increase of nitrogen in those samples grown with the application of this element over that found in the check plots for each variety of wheat and in each section. This increase equals from one to six-tenths of one percent. This difference is consistent, too, throughout the statement for the wet, dry and true-gluten. It has frequently been shown that the nitrogen content of wheat can be increased by the application of sodic nitrate and also by ammoniacal salts. This statement is also made in regard to other nitrogenous manures, sheep manure for instance. This statement, according to our observation, needs the following modification: Provided the nitrogen is converted into nitric-nitrogen with sufficient rapidity. We have used only one form of nitrogen in our experiments at Fort Collins, sodic nitrate, but we have one set of samples grown with farmyard manure, which gives different results. Our samples grown with the application of nitrogen, in the form of sodic nitrate, regularly show an increase in the nitrogen content of the crops. Crops grown with farmyard manure, show a decided advantage in yield, both of straw and grain, but only a very small increase in the nitrogen content. The maximum difference in any one of the three pairs of samples was 0.20 percent nitrogen; the other two pairs show a difference of 0.01 and 0.05 percent respectively. The greatest difference, 0.20 of one percent, may be due to other causes than the manure, but as the record stands, this difference would be attributed to its effects. These samples were obtained for another purpose and will be given in connection with the subject that they are more specifically intended to illustrate. I have not used ammoniacal salts on any plots, and can only state, on the authority of others, that their effects are the same as those of nitrogen in the form of sodic nitrate.

Two other questions present themselves for consideration in this connection, namely, are there any effects produced by the other plant

foods which we can recognize as specifically due to them, and are our analytical results accurate enough to justify us in assuming that the differences found are well enough established to be taken as the basis of inferences in regard to these effects? We should extend these questions to include regularity in the direction of these differences, not only for the samples of the different varieties for one year, but in these same varieties for several years.

I am very firmly convinced that minute differences as expressed in percentage composition correspond to very significant differences in the properties of the wheat, provided that we can be certain that the percentages obtained are correct within limits, as narrow as or narrower than those with which the properties of the grain actually vary. I fear that it is so difficult to attain to this degree of certainty in regard to our analytical results, that these questions in regard to the specific effects of fertilizers and the manner in which they modify one another must remain in some doubt.

The analyses given in the preceding tables are all based on the air-dried grain. The moisture in our samples is quite constant for the individual varieties grown on the same section of land. There is but one instance in nine groups of four samples each in which we find a difference as great as or greater than 1 percent, so that the differences in the percentage, of potassium, for instance, due to this variation will fall in the third decimal place and will be less than five. The ash constituents in the wheat were determined by one analyst, and the phosphorus and potassium in the general analyses of wheat by another. The methods used in the case of the phosphorus were the same, but they used different methods in determining the potassium. The difference in the percentages of the potassium due to this cause is from two to three one-hundredths of 1 percent. A comparison of the results obtained will show but one or two serious discrepancies. On the other hand, we find such agreement in the big features of the results that we can accept them as established on a pretty firm basis.

There are reasons why we should prefer not too accept the results of the 1913 crop as indicative of the effects of the soil factors upon the composition of the wheat. One reason is that the land had been in other crops during the preceding years and we do not know with as much certainty as we should the conditions preceding the growing of this crop. On the other hand, this crop grew and matured under favorable weather conditions, and probably gives us the most representative samples of our average wheat that we have obtained, but it is doubtful whether it gives us the best illustration of the influence of the soil factors upon the composition of the wheat.

EFFECTS OF FERTILIZERS ON THE THICKNESS OF THE BRAN

It is usual to take the nitrogen content as the principal criterion in judging the differences in wheat. The other constituents usually given in an analysis, moisture, ash, fat, fiber, and even starch, are of much less importance. The crude fiber as determined in the wheat corresponds roughly to the epidermal portions of the wheat, and in a rough way indicates the relative thickness of these parts. It might be interesting from an anatomical standpoint, to know whether the fertilizers influence these protective features of the grain or not, and how, but for our purposes these points are not of much interest and the results of the 36 analyses of wheat grown on our own plots, presented in the preceding tables, indicate no decisive and constant difference. The range of these determinations in the 36 samples is from 2.400 to 3.007 percent, or a maximum variation of 0.607 percent. The average percentage of crude fiber in the samples grown with application of nitrogen is, taken literally, the least of the four averages and that of those grown with potassium, the highest. The difference is 0.12 percent, too small for consideration from our standpoint. The starch, owing to its large percentage, will reflect the variation in the protein, the substance present in the next largest quantity; these two substances present in wheat in the largest quantities must bear an inverse relation to one another. There is nothing in our analyses to show that this is anything more than a numerical relation. If there be any other relation between these substances it is not shown by our results so far given. The formation of starch or carbohydrates, in general, may influence that of the protein or vice versa, but this is a physiological relation which our work does not present. The question of flinty and mealy kernels probably comes within the province of this relation. We have shown in Bulletin 205 that this is directly a question of the ratio between the nitrogen and potassium present in the soil and available to the plant. The ash in the analyses given was determined by the usual method of incineration, i.e., charring, extraction with water and subsequent ignition. There is no question but that some loss occurs in this method, but not enough to vitiate the results. The nine sets of samples agree in showing that those grown with the application of nitrates are a little lower than the others. This will be found to be the rule, but it is not altogether without exception. It is owing to difficulties in preparing the ash of grain and also of the straw that I have used the form "ash-constituents" in stating the analytical results of such determinations for both wheat-straw and grain. Leavitt and Le Clerc* have shown that there may be a very considerable loss of phosphorus in direct calcination. They found the difference between incineration at low redness and "redness" to equal 46.0 percent of the

* Journal Am. Chem. Soc., Vol. 30, pp. 391-394.

phosphoric acid, that between incineration at "redness" and the acetate method to be equal to 35.0 percent of the P_2O_5 . Without any knowledge of the results obtained by these authors, I found that it is practically impossible to obtain correct results in making this determination by igniting at a very low temperature, in a partially covered crucible over a very low Bunsen flame. I made a series of 38 determinations by ignition, and by dissolving in concentrated nitric acid with the addition of a sufficient quantity of magnesian oxide and subsequent ignition, and found the differences ranging from 10.0 to 37.0 percent of the phosphorus present. The determination of phosphorus in straw by ignition is still more difficult, owing to the excess of silica and carbon which, at a comparatively low temperature, may cause the volatilization of practically the whole of the phosphorus.

Leavitt and LeClerc think that the loss of phosphorus in making the determination of total ash in grain may be neglected.* According to our observations, the method of charring and extracting with water is unsatisfactory, especially if we are to consider differences of one or two tenths, or even hundredths of 1 percent, as significant of the effects of fertilizers or weather conditions. The results given in the preceding tables were obtained by this method, and we justify the use of these results on the supposition that, the method having been worked in a uniform manner, the results have an error, but this is common to all of them and in the same direction. The ash, or mineral-constituents, given in the table under the latter caption, were not determined by preparing an ash by the usual incineration. The air-dried wheat was dissolved in concentrated nitric acid and subsequently ignited, but this is not the place for these technical details.

The standards adopted for reference are averages given by Leach in his work on "Food Inspection and Analysis". Reference will also be made to Hungarian wheats given by Kosutany.

* Loc. Cit.

AVERAGE COMPOSITION OF WHOLE WHEAT*

Weight of 100 kernels	Domestic	Foreign
	3.866 grams	4.076 grams
	Percent	Percent
Moisture	10.62	11.47
Protein	12.23 (11.16 Nx5.7)	12.08 (11.02 Nx5.7)
Fat	1.77	1.78
Fiber	2.36	2.28
Ash	1.82	1.73
Carbohydrate (Diff).....	71.18 (72.27)	70.66 (71.72)
Wet Gluten	26.46	25.36
Dry Gluten	10.31	9.82

Leach gives a somewhat fuller analysis of wheat, taken from a tabulation of the composition of the principal cereal grains by Villier and Collin†.

Water	13.65
Protein	12.35 (11.25 Nx5.7)
Fat	1.75
Sugar	1.45
Gum and Dextrin.....	2.38
Starch	64.08
Cellulose	2.53
Ash	1.81

THE COMPOSITION OF HUNGARIAN WHEAT

The following table giving the data pertaining to the composition of Hungarian wheat is of interest, if for no other reason, because of the universally high reputation of Hungarian flour. I have preferred to give Kosutany's data for each of the six seasons rather than to average them, for this would obscure, or entirely conceal, the seasonal differences.

*Leach "Food Inspection and Analysis," p. 272.

†Leach "Food Inspection and Analysis," p. 271.

MINIMUM, MAXIMUM AND AVERAGE COMPOSITION OF HUNGARIAN WHEAT*

Harvest	Weight per 1000	Mealiness	Moisture	Ash	Fat	Fiber	Nitrogen	Protein	N-free	Wet		Dry	
										Gluten	Gluten	Gluten	Gluten
Minimum	24.67	20.44	10.95	1.129	1.709	1.129	1.733	10.836	64.824	15.00	5.75		
Maximum	41.72	75.10	14.40	1.958	2.309	1.958	2.731	17.074	70.811	34.45	11.95		
Average 50/50	31.424	41.857	12.612	1.735	2.056	1.735	2.106	13.162	67.915	21.70	7.962		
								(12.004)†					
								(Nx5.7)					
Minimum	23.11	4.50	11.602	1.38	1.673	1.860	1.846	11.534	61.34	17.00	6.85		
Maximum	38.50	75.87	15.162	2.26	2.399	3.351	2.950	18.434	70.06	43.40	14.80		
Average 57/57	29.38	24.56	13.545	1.73	2.051	2.471	2.298	14.366	65.78	26.77	9.87		
								(13.099)					
								(Nx5.7)					
Minimum	23.90	4.12	11.79	1.22	1.61	1.69	1.380	8.63	63.58	18.50	6.85		
Maximum	40.24	77.87	16.86	1.96	2.30	2.43	2.600	16.25	71.77	50.75	15.30		
Average 53/53	31.42	36.44	14.57	1.58	1.94	2.01	1.897	11.86	68.04	26.17	9.64		
								(10.83)					
								(Nx5.7)					
Minimum	27.60	6.24	9.99	1.40	1.41	2.02	1.667	10.42	67.40	23.95	7.32		
Maximum	43.16	71.24	11.34	1.89	1.73	2.74	2.624	16.40	73.43	44.87	14.75		
Average 53/53	34.39	33.71	10.82	1.66	1.54	2.36	1.991	12.44	71.17	30.30	10.21		
								(11.35)					
								(Nx5.7)					
Minimum	26.63	0.00	10.34	1.44	1.44	2.06	1.684	10.54	67.13	22.90	8.12		
Maximum	42.88	62.00	11.40	1.91	1.84	2.72	2.803	17.52	72.94	52.00	15.90		
Average 53/53	33.78	24.09	10.80	1.66	1.60	2.31	2.122	13.23	70.36	32.72	11.63		
								(12.20)					
								(Nx5.7)					
Minimum	27.53	0.00	10.03	1.41	1.34	2.01	1.750	10.94	61.94	24.55	8.33		
Maximum	40.17	82.00	11.23	1.98	1.88	2.66	3.395	21.22	72.82	52.55	18.83		
Average 53/53	36.62	26.08	10.91	1.73	1.61	2.30	2.319	14.37	69.09	37.33	12.11		
								(13.22)					
								(Nx5.7)					

*Kosutany, "Der ungarische Weizen und das ungarische Mehl"—pp. 102-108.

†I have added the product, Nx5.7, because we have used this factor, while Kosutany used 6.25.

CHECK SAMPLES OF 1913 REPRESENT NORMAL COLORADO WHEAT

In my judgment we have no set or sets of samples which are more fairly representative of normal Colorado wheat than the check samples grown in 1913. We may include with these the samples grown with the application of potassium and also those grown with the application of phosphorus, but not those grown with the application of nitric nitrogen. My reasons for including the former, but not the latter samples, are that the former differ less from those grown on the check plots in their physical properties, than samples grown in the same district differ from one another, but which is not true of those grown with the application of nitrates. It is true that we find the same kind of differences, and as great, in the samples of wheat grown in different sections of the State, as we find in our samples grown under different conditions, but the marked exceptions of this character, which have fallen under my observation, have been due to an unusual supply of nitric-nitrogen formed in the soil. We would obtain a better average for our wheats by including the samples grown with the applications of nitric-nitrogen, but our object is to present the facts, as nearly as we may see them, and not to present a good average composition for our wheat.

In the following statement, the analysis given under each section is the average of wheat from three plots, a check plot, a plot with the addition of phosphorus and one with the addition of potassium. The average in each case is really the average of nine analyses. The varieties are given and no remarks are needed in this place.

AVERAGE COMPOSITION OF WHEATS (IN PERCENT) GROWN WITHOUT THE APPLICATION OF NITROGEN IN 1913*

	Defiance				Red Fife				Kubanka			
	Sec. 1700	Sec. 1800	Sec. 1900	Avg.	Sec. 1700	Sec. 1800	Sec. 1900	Avg.	Sec. 1700	Sec. 1800	Sec. 1900	Avg.
Moisture		11.447	10.836	11.731	11.338	10.534	10.179	10.403	10.525	11.218	11.099	11.047
Ash		1.927	1.819	1.931	1.893	2.024	2.049	2.067	1.966	1.908	1.937	1.937
Fat		1.686	1.728	1.798	1.771	1.787	1.755	1.829	1.979	1.890	1.840	1.903
Fiber		2.578	2.696	2.568	2.614	2.783	2.621	2.361	2.532	2.579	2.561	2.557
Nitrogen		2.047	2.133	1.955	2.045	2.301	2.425	2.450	2.154	2.105	2.216	2.158
Protein (Nx5.7)		11.668	12.159	11.140	11.656	13.103	13.825	13.968	12.279	11.997	12.630	12.302
Starch		61.674	62.321	63.578	62.558	62.185	61.661	62.479	61.067	62.526	62.288	61.961
Sucrose		1.245	1.311	1.223	1.256	1.419	1.153	1.384	1.411	1.450	1.452	1.438
Wet Gluten		24.450	24.690	22.220	23.790	27.460	27.680	28.210	26.840	25.780	25.870	26.160
Dry Gluten		9.930	10.050	9.230	9.770	11.070	11.220	11.470	11.260	10.760	10.840	10.950
True Gluten		7.045	7.150	6.394	6.863	7.996	8.182	8.261	7.913	7.567	7.748	7.743
Phosphorus		0.445	0.422	0.472	0.446	0.467	0.460	0.511	0.438	0.414	0.445	0.432
Potassium		0.435	0.437	0.476	0.449	0.466	0.424	0.465	0.472	0.463	0.487	0.473

• Each analysis in this table is an average of three analyses.

THE EFFECT OF NITRATES ON NITROGEN CONTENT

That the nitrogen content of wheat may be increased by the application of sodic nitrate or ammonia salts, has been known a long time, so there is nothing new in the statement of the fact. The nitrates impart characteristic physical properties to wheat grown with their application. These properties are usually considered desirable if the nitrate is not added in too large quantities. The following analyses are given to show to what extent the chemical composition was affected, and also to show why we omitted them from the samples taken as representative of our wheats. The reason, for the present time at least, may be stated to be that they are quite different from the average of wheats grown without it. The statement of the analyses will show how different they are, and to what extent the composition of the wheat responds to the application of various amounts of this salt. The results in this respect increase with the amount applied, but the effect produced is not proportional to the amount, i.e., the minimum amount produces a certain result; three times this amount will not necessarily produce three times this effect, it may be more or less than three times. The same is true of the physical characteristics of the berries, the larger amounts showing a strong tendency to produce shrunken berries.

AVERAGE COMPOSITION OF WHEATS (IN PERCENT) GROWN WITH APPLICATION OF NITROGEN—1913

	Defiance				Red Fife				Kubanka			
	Nitrogen Per Acre				Nitrogen Per Acre				Nitrogen Per Acre			
	120 lbs.	80 lbs.	40 lbs.	Avg.	120 lbs.	80 lbs.	40 lbs.	Avg.	120 lbs.	80 lbs.	40 lbs.	Avg.
	Sec. 1700	Sec. 1800	Sec. 1900		Sec. 1700	Sec. 1800	Sec. 1900		Sec. 1700	Sec. 1800	Sec. 1900	
Moisture	11.825	10.818	11.763	11.469	10.408	9.828	10.363	10.200	11.410	11.780	11.515	11.568
Ash	1.921	1.848	1.851	1.873	1.823	1.928	1.961	1.904	1.869	1.721	1.822	1.771
Fat	1.598	1.728	1.728	1.685	1.815	1.810	1.803	1.809	2.078	1.995	1.878	1.984
Fiber	2.362	3.007	2.532	2.634	2.630	2.684	2.512	2.609	2.382	2.830	2.437	2.598
Nitrogen	2.630	2.435	2.290	2.452	2.665	2.616	2.543	2.608	2.528	2.414	2.261	2.401
Protein (Nx5.7)	14.989	13.788	13.051	13.943	15.188	14.909	14.493	14.863	14.411	13.758	12.887	13.719
Starch	59.788	60.264	63.486	61.179	60.192	60.002	61.956	60.717	59.310	60.894	61.272	60.492
Sucrose	1.142	1.051	1.306	1.166	1.249	1.329	1.438	1.339	1.697	1.449	1.656	1.601
Wet Gluten	35.370	31.330	24.330	30.343	36.070	32.200	30.070	32.780	32.930	30.100	28.800	30.610
Dry Gluten	13.980	12.320	10.130	12.150	13.830	12.840	12.260	12.980	13.490	12.300	11.820	12.540
True Gluten	10.340	9.220	7.241	8.934	10.200	9.487	8.709	9.465	9.857	8.530	8.407	8.931
Phosphorus	0.442	0.393	0.454	0.423	0.452	0.405	0.479	0.445	0.404	0.373	0.419	0.399
Potassium	0.440	0.446	0.476	0.454	0.488	0.466	0.501	0.485	0.482	0.423	0.461	0.455
Weight per 1000	32.730				34.360				42.180			
General Avg.	11.079				11.568				11.079			

NITRATES CAUSE A DEPRESSION OF PHOSPHORUS

The physical characteristics of the berries produced by the application of nitrogen have already been mentioned. These kernels are relatively small, flinty, translucent, hard, and often shrunken. The marked feature of the composition is the increase in the nitrogen content; and with this, in the wet, dry, and true gluten. The differences between the phosphorus in the general averages given in the last two tables differ only a few hundredths of 1 percent, but a comparison of the phosphorus given in the other analyses shows that this element is regularly lower in the nitrate samples, than in the others. In other words, assuming that the check plots give us wheat of normal phosphorus content, the nitrates have caused a depression of this element.

NITRATE-FERTILIZED PLANTS MORE SUSCEPTIBLE TO RUST

In Bulletin 208, and again in Bulletin 217, it was shown that nitric-nitrogen produces marked effects upon the composition of the plant in that it increases all forms of nitrogen in the plant throughout the season; further, that it exercises a decided influence upon the mineral constituents of the plant; first in depressing the silicon, second in increasing the calcium, potassium and magnesium, but does not effect the phosphorus. Its effect upon the phosphorus in the grain is to depress it. This is quite evident in the table entitled "Mineral Constituents of Wheat, Crop of 1913". The difference in the general averages given in the two preceding tables is small, but this difference is persistent and, with few exceptions, plainly appears in individual analyses. The effect upon the amount of potassium is in the same direction in both plant and grain, namely to increase it, but this is less marked in the grain than in the plant. The whole character of the plant and its products, as well as its appearance, is, according to this, greatly affected by the supply of nitric-nitrogen in the soil. This conclusion is entirely in harmony with the deportment of the plant, which lodges easily, and when not lodged often shows marked abnormality in ripening, the middle portions of the plants and leaves remaining green, or at least very immature, while the top and bottom portions appear, and I think are, ripe. Further, I do not think that any doubt can be entertained that these plants are much more readily attacked by rust, than others of the same variety grown with other fertilizers or with none. There are differences which are known and really need no mention, such as the softness of the straw, a feature which is evident to persons handling it. There is a marked depression of silicon ranging from 14 to 29 percent of the total in the plant. I do not know how significant this difference may be, nor do I know that the weakness and softness of the straw is dependent upon this difference; I do not intend to attempt

to give an explanation of these facts. It is, however, clear that both the plants and grain grown with the application of nitrates are different in chemical composition as well as in physical properties from those grown without them. These latter, and, in fact, the former also, are those ascribed to hard wheats, small, translucent, dark amber, flinty berries with high nitrogen content, at least, higher nitrogen content than wheat of the same variety grown under otherwise identical conditions, including both soil and climate.

COMPARISON OF STANDARDS ADOPTED AND RESULTS GIVEN

It may now not only be permissible, but advisable, to point out some of the relations between the standards adopted and the results given by our general samples, as well as with our wheats grown under more definitely known conditions.

I take it that the average given by Leach in his work includes both spring and winter-wheat, and some allowances should be made for this fact, though it does not appear from our general samples that there is any distinction to be made in regard to nitrogen content or degree of mealiness. Nevertheless, it is proper to remember that the wheats experimented with are all spring-wheats, though I do not believe that emphasis should be laid upon this fact. The weight per 1,000 kernels varies with the varieties. The average for the Defiance grown without nitrate is 39.18, for Red Fife 35.29 and for Kubanka 44.42 grams. Two of them are higher than the averages given for domestic wheats and one lower. The Red Fife is a small-kerneled wheat and the Kubanka, as it ordinarily grows with us, a large-berried one. In these counts all kernels were taken, and the wheat had not been screened after threshing. Carefully screened wheat should give a higher weight per thousand. The chief feature in the statement of the composition is the close agreement between the standards given and our averages, even the protein differs less from that given in the standards than some of our individual samples not grown with the application of nitrogen differ from one another. The standard for domestic wheats is 11.16 percent ($N \times 5.7$), for foreign wheats 11.02 ($N \times 5.7$); we obtain 12.53 percent. The starch is quoted from Villier and Collin as 64.08; we obtain 62.20 percent. The wet gluten is so dependent upon the manipulator that its value is but small; the dry gluten is a much better criterion and this we find given as 10.31 percent for domestic wheat, ours gives 10.68 percent. If we average the six crops of Hungarian wheat given by Kosutany, we obtain for protein 12.10 ($N \times 5.7$) and for dry gluten 10.24; figures very close to those given by our Colorado wheats, 12.53 and 10.68 respectively. The Hungarian wheats do not average so high in their absolute weight as ours, 1,000 grains averaged for the six years 32.83 grams. One of these six years yielded grain apparently somewhat smaller in kernel than usual and was, perhaps, an abnormal

one, still the maximum average is only a little above the maximum for our smallest grained variety, the Red Fife, i.e., 36.62 against 35.94.

The general samples of winter-wheat average 13.31 percent protein and 11.59 percent dry gluten, the general samples of spring-wheat average 13.32 percent protein and 11.74 percent of dry gluten. Each of these pairs of averages is higher than the corresponding data for our spring-wheats, but lower than for our samples grown with nitrates; 14.18 percent protein, 12.56 percent dry gluten. Objection has been offered in previous paragraphs to accepting general samples, because it is practically impossible to ascertain a correct statement of the conditions under which they were grown, and quite as difficult to learn the extent to which the samples are representative as the quality of the samples will depend upon the judgment of the sender. The averages given above for the general samples have but little value for these very reasons. The lowest percentage of protein found in the 1912 crop of winter-wheat, grown at Fort Collins, was 14.15, while Turkey Red, grown at La Jara, contained only 8.22 percent, and Red Chaff, grown at Eckert, contained 10.05 percent. These differences are indicated by the physical properties of the kernels, but this is not enough to make known the conditions under which the wheats were grown. These low-protein wheats are extreme cases of mealy wheats, whereas, our Fort Collins samples are fairly flinty wheats, though mixed. Could we but know the soil conditions under which the various samples were grown, these differences, in most cases, would be explicable, as I have pointed out in the case of three samples of Turkey Red, grown in the same section of country, from the same lot of seed, under the same climatic conditions, and also, it is safe to assume, of irrigation, which, as we have already stated, has but little influence, provided the plants have a sufficient supply of water at the critical period in their development. We shall come back to the question of the effect of irrigation, not to that of a critical period which is here referred to, perhaps, in too general a manner. I feel entirely justified in referring to such a period by the marked effects, which I have seen produced by a delay of a few days in the application of water, upon the development of the crop. Returning to the general samples, which include some dry-land wheats, it is proper to state that these are not, as is often, if not usually, considered richer in protein than the irrigated wheats. The few samples that we have analyzed would rather support the opposite view. The same is true of the physical properties, for we find samples of dry-land wheat badly affected by mealiness, which is equivalent to saying relatively low in protein.

COLORADO WHEAT EQUAL TO BEST IN CHEMICAL COMPOSITION

So far as chemical composition is concerned, the data given indicates that our average wheat, which shows a varying percentage of

mealiness, is equal to the very best of wheats. Further, that the two extremes, small-grained flinty wheat, on the one hand, and mealy wheat on the other, differ materially from the average wheat which is a mixture of these two kinds, the former may be taken as carrying not far from 2 percent more protein and the latter 3 percent, or more, less than the average.

We have intentionally chosen conditions which present the results obtained under favorable weather conditions to as great an extent as possible, allowing the effects of our fertilizers upon the physical and chemical characteristics of our wheats to come out in the fullest, possible light. These effects have been shown to be determinative of those physical properties designated as hard and soft, which is in agreement with the conclusions given in Bulletin 205. Further, that these physical properties correspond to very deep-going differences in the composition of the plants and kernels, but the effects upon the composition of the kernels are even more radical, so far as we are able to interpret the results, than upon that of the plant. This is particularly apparent in the effects of nitric-nitrogen upon the crop. While the effects of potassium are quite evident, they are not so striking as those of the nitrogen. The effects of these fertilizers or plant-foods are antagonistic, in that, one increases the nitrogen content while the other tends to depress it, regularly in the stems and leaves of the plants, and in the case of a sufficient predominance to produce yellow-berry, to depress it greatly in the kernels. The phosphorus showed no regular and consistent effect upon the amount of nitrogen and was, in general, surprisingly indifferent in its results.

One of the reasons assigned for taking the samples grown in 1913 as representative of the normal wheat crop in Colorado was that the weather conditions throughout the season were more nearly normal than those of 1914 and 1915.

In some respects the season of 1914 was as favorable, if not more so, than that of 1913. But there was one feature which seriously affected our results; this was a short period of wet weather near the end of July, just before the ripening period of the grain. At the very end of this period we had a shower of short duration, but very heavy. How this injury suffered by the crop is to be apportioned between the whole period and the closing feature of it, I do not know, nor do I know how much to attribute to the direct injury caused by the weather, and how much to the indirect injury caused by the development of rust. I think that a very large amount of the injury should be attributed to the latter.

TIME AND MANNER OF RAINFALL, RATHER THAN QUANTITY, IMPORTANT TO CROP

The experiments were conducted on the same land and were in all respects duplicates of those of 1913. This means that we had wheat

after wheat on the check and other plots with the same fertilizers as were applied the season before. The land was irrigated after the crop of 1913 had been removed. The stubble was disced in and the land plowed a few weeks later. The promise of the crop of 1914 was most flattering up to the end of July, at which time, as stated above, untoward conditions intervened, the most serious of which was, probably, the rust, but this was undoubtedly the result of the weather conditions. The rainfall during the last 10 days of July, 1914, was 1.38 inches, of which 0.87 inches fell on the 30th in less than two hours. The mean temperature during this period was 69.3 degrees F. In 1913 we had in the last 11 days of July, 1.53 inches and a mean temperature of 62. Nearly the whole of this fell on the 22, 23, and 24th and was followed by bright, cool weather. The grain was not beaten down and did not rust. It is evident that the time and manner of the rainfall and the conditions following it, rather than the amount of water, are the factors which come into play, for the rain in 1913 exceeded that of 1914, but was not followed by any bad results, whereas, the rainfall of 1914, the greater part of which fell on 30 July, was quite disastrous to the Defiance and injured the other varieties. Rust developed freely, especially on the Defiance, which it very seriously damaged, in fact, ruined.

We have given the average composition of our samples for 1913, excluding those in which the nitrogen had been increased by the application of nitrates because we do not consider them truly representative. The average protein content ($N \times 5.7$) was 12.53 percent and that of the plots receiving nitrogen was 14.18, a difference of 1.65 percent. The physical properties of these wheats, as well as their composition, are so different that their elimination from the average is not only justified, but necessitated as a matter of fairness.

We have not given the meteorological details of the season of 1914, but we have stated that they were favorable up to 30 July, and that the promise of an excellent yield of good grain was all that could be desired.

A point suggested in a preceding paragraph relative to the order of the crops, i.e., wheat after wheat without and also with fertilizers, may occur to the reader as important in regard to the effect of this fact upon the wheat, its growth and composition. I willingly acknowledge that this point is not covered by my data, and that we are dependent on observations upon the growth and development of the plants, together with the yields obtained to answer this. The growth and development of the plants up to 30 July was more vigorous than in 1913. The plants were large, the head long, and the kernels were already well filled out but still soft when the rain came.

The correlation table given in Bulletin 217, p. 22, gives data setting forth the size of plants, length of heads, etc., and, with the table

of yields, the weight per bushel, and the ratio of straw to grain given in this bulletin, shows that the check plots, except in the case of the Defiance, gave materially higher yields in 1914 than in 1913, and the weight per bushel was very high. In 1913, the Defiance check plots yielded 41.4, 40.6, and 41.3 bushels per acre, average 41.1 bushels, weight per bushel 62.3 pounds; in 1914, the average yield was 31.1 bushels, weight per bushel 56.7 pounds; in 1915, yield 19.5 bushels, weight per bushel 49.6 pounds. The Red Fife check plots averaged in 1913, 33.2 bushels, weight per bushel 64.0 pounds, and in 1914, 47.2 bushels, weight per bushel 63.7 pounds; in 1915, 32.6 bushels, weight per bushel 60.8 pounds. The Kubanka checks averaged in 1913, 34.2 bushels per acre, weight per bushel 63.2 pounds, in 1914 the same plots averaged 47.8 bushels per acre and the weight per bushel was 64.9 pounds; in 1915, 32.8 bushels and weight per bushel 62.3 pounds. The data given in the correlation table and the comparative yields and weights per bushel, given for the three seasons answer fully the questions arising in connection with the succession of crops and exhaustion of the soil. The plants were well developed, the yields good and the weight per bushel, except in the case of the Defiance, above the average in each of three years.

The total rainfall in July, 1913, was 2.63 inches and the mean temperature 66.8 degrees F.; in 1914 the rainfall was 1.68 inches and the mean temperature 68.3 degrees F.; and in 1915 the rainfall was 2.12 inches and the mean temperature 64.74 degrees F.

In 1913 and 1914, we had but little cloudy weather, while in 1915 it was prevalent. We had only 11 days in July, 1913, which are recorded as clear. The weather conditions in August were good, especially in 1913 and 1914, but were not quite so favorable in 1915. In 1913, we had no rain in August prior to harvest, in 1914 we had 0.29 inches and in 1915, 0.57 inch. This 0.57 inch of rain did not interfere with our harvest, and it is a question whether it made our conditions any worse than they were already. I am quite certain that it would have done us no harm had it not been preceded by bad conditions in July, for the grain would have been so mature by this time that practically no injury would have resulted. We can, I think, with entire justice, neglect the weather conditions in August, not that I wish to assert that the one-half inch of rainfall in early August might not have injured our crop, but, as will appear later, bad conditions in the latter part of July, with very good conditions in early August, will produce very bad results, so I feel justified in neglecting the August conditions. Two things, of course, are here assumed as the causes of the bad results, one is the unfavorable weather conditions already mentioned, and the other is the condition of development of the plant at this time. That this latter factor cannot be too strongly emphasized is evidenced by the effects of these bad conditions on the Defiance wheat, compared with

the same upon the Red Fife. That there may be a difference in the ability of these two varieties to withstand unfavorable conditions is very probable, still it is a fact that the Fife matures several days earlier than the Defiance when sown on the same date, and by the end of July is usually quite mature. I have, in a preceding paragraph, given the results of the seasons on the comparative yields of our check plots and it will be noticed that the effects of the same conditions were much less upon the Red Fife than upon the Defiance, which fact I attribute largely to the stage of development of the plants at the time the weather conditions caused the injury to the crop.

In the statement for the rainfall for July of each season, it will be noticed that we had the heaviest rainfall in 1913 and the next heaviest rainfall in 1915. The former crop was excellent in quality, so far as weight per bushel and chemical composition are concerned; and the latter, as we shall later see, while good in yield and weight per bushel for the Red Fife and Kubanka, was of inferior chemical composition. In these cases, it was not the amount of water that fell during the month that produced the inferior wheat, for the larger amount of rainfall was followed by the better quality of wheat. The distribution of the rainfall in the two seasons was quite different. In 1913 practically the whole of the rain fell between the 18th and 23rd, and during the month we had but one wholly cloudy day. In 1915 we had very different conditions, the rainfall was distributed more evenly throughout the month, especially through the last few days of it, and there was much cloudy weather. We also had heavy dews. The difference in mean temperature during the month in the two seasons was comparatively small, 66.8 degrees F., in 1913 and 64.7 degrees F., in 1915, or a difference of 2.1 degrees F. This statement relative to the difference in mean temperature is, perhaps, not quite sufficient, for the character of the grain is determined, or may be, by a much shorter period than the 31 days composing the month; for this reason the mean temperature during the last 10 days of the month may be given; this was 62.4 in 1913, and 65.9 in 1915. This difference, though small, only 3.5 degrees, together with the continuous wet weather, with cloudiness and heavy dews, and with the vigorous growth of plants, favored an abundant development of rust. We had somewhat the same conditions in 1914 as in 1915 with the difference that in 1914 the rain came mostly in one violent shower, which beat the grain down so that it formed a thick mat of green plants through which the ventilation was considerably impeded, with the result that rust developed with special abundance on the Defiance, and quite abundantly on the other varieties. I have unfortunately, no means of conveying a definite idea of the comparative severity of these attacks. The composition of the crops for the two seasons is given in the following tables, which also give the sections of land, the fertilizers and the amounts used:

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Variety	Fertilizer per acre	Section 1700										Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
		Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent						
Defiance	120 lbs. nitrogen.....	8.755	2.086	1.855	3.812	2.203	12.557	59.832	1.175	30.17	12.31	9.129	0.429	0.547	21.15	
Defiance	60 lbs. phosphorus.....	9.220	1.675	1.938	3.391	1.578	8.995	63.900	1.125	18.50	7.87	5.529	0.410	0.466	27.19	
Defiance	200 lbs. potassium.....	9.420	1.585	1.863	3.229	1.501	8.585	65.177	1.113	20.50	8.59	6.013	0.377	0.484	31.01	
Defiance	None	8.555	1.880	1.775	3.480	1.547	8.816	66.330	1.136	18.23	7.66	5.435	0.404	0.442	26.97	
Red Fife	120 lbs. nitrogen.....	9.488	1.690	1.878	3.020	2.099	11.964	63.216	1.218	29.80	12.61	8.908	0.409	0.415	32.50	
Red Fife	60 lbs. phosphorus.....	9.058	1.884	1.890	2.891	1.668	9.508	65.340	1.332	23.13	9.67	6.848	0.420	0.413	33.88	
Red Fife	200 lbs. potassium.....	9.250	1.772	1.915	2.845	1.780	10.143	63.576	1.335	24.57	10.21	7.087	0.420	0.412	35.69	
Red Fife	None	9.385	1.938	1.920	3.017	1.661	9.468	64.602	1.260	22.40	9.31	6.637	0.398	0.425	33.85	
Kubanka	120 lbs. nitrogen.....	9.130	1.704	1.925	2.995	2.106	12.001	61.002	1.341	33.17	13.57	9.386	0.352	0.455	38.15	
Kubanka	60 lbs. phosphorus.....	9.375	1.922	1.995	2.995	1.713	9.764	65.567	1.341	25.00	10.57	7.266	0.391	0.452	41.18	
Kubanka	200 lbs. potassium.....	9.858	1.762	1.888	2.932	1.842	10.499	64.494	1.409	26.17	11.02	7.632	0.386	0.461	44.20	
Kubanka	None	8.535	1.752	2.018	3.002	1.842	10.499	64.728	1.467	26.97	11.38	8.048	0.394	0.440	42.68	

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Fertilizer per acre	Section 1700				Amid				Albumin				Gliadin				Total	
		Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent	Nitrogen Percent
Defiance	Nitrogen, 120 lbs...	0.0699	0.2517	1.0439*	0.8375	2.2030													
Defiance	Phosphorus, 60 lbs..	0.0523	0.1888	0.5954	0.7415	1.5780													
Defiance	Potassium, 200 lbs..	0.0453	0.1678	0.5977	0.6902	1.5010													
Defiance	None	0.0453	0.2168	0.4952	0.7892	1.5465													
Red Fife	Nitrogen, 120 lbs...	0.0734	0.2028	0.7467	1.0761	2.0990													
Red Fife	Phosphorus, 60 lbs..	0.0488	0.1888	0.6736	0.6568	1.6680													
Red Fife	Potassium, 200 lbs..	0.0488	0.1818	0.6736	0.8753	1.7795													
Red Fife	None	0.0734	0.1678	0.4671	0.9427	1.6610													
Kubanka	Nitrogen, 120 lbs...	0.0523	0.2307	0.9030	0.9195	2.1055													
Kubanka	Phosphorus, 60 lbs..	0.0523	0.1888	0.7539	0.7180	1.7130													
Kubanka	Potassium, 200 lbs..	0.0418	0.2028	0.7038	0.8936	1.8420													
Kubanka	None	0.0488	0.2098	0.7853	0.7981	1.8420													

*This was repeated with same results.

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Section 1800																	
Variety	Fertilizer per acre			Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	80 lbs. nitrogen	.....	8.453	1.755	1.960	3.380	2.092	11.924	60.732	1.074	31.07	12.38	8.691	0.346	0.436	23.77	
Defiance	40 lbs. phosphorus	.....	8.933	1.825	1.925	3.265	1.644	9.367	64.206	1.081	19.37	8.14	5.687	0.393	0.431	27.05	
Defiance	150 lbs potassium	.....	9.060	1.760	1.838	3.279	1.578	8.995	64.566	1.068	21.07	8.82	5.815	0.375	0.412	30.04	
Defiance	None	.....	8.918	2.017	1.913	3.571	1.835	10.460	63.144	1.057	24.40	10.09	7.000	0.426	0.437	25.67	
Red Fife	80 lbs. nitrogen	.....	8.783	1.697	1.860	3.135	1.922	10.955	62.280	1.139	28.73	11.80	8.377	0.364	0.398	30.42	
Red Fife	40 lbs. phosphorus	.....	8.703	1.812	1.930	3.113	1.668	9.468	62.910	1.272	21.67	8.78	6.304	0.399	0.405	33.39	
Red Fife	150 lbs. potassium	.....	9.140	1.867	1.838	3.062	1.724	9.824	63.774	1.335	23.03	9.46	6.764	0.403	0.403	34.34	
Red Fife	None	.....	8.485	1.947	1.903	2.960	1.794	10.223	63.144	1.221	25.77	10.42	7.459	0.412	0.437	31.50	
Kubanka	80 lbs. nitrogen	.....	9.455	1.703	1.933	2.992	2.168	12.358	61.255	1.386	32.83	13.72	9.520	0.343	0.418	40.02	
Kubanka	40 lbs. phosphorus	.....	10.043	1.903	2.115	3.221	1.714	9.767	65.214	1.455	24.73	10.57	7.316	0.397	0.436	42.19	
Kubanka	150 lbs. potassium	.....	9.613	1.712	1.875	2.970	1.925	10.972	64.206	1.461	27.33	11.62	7.665	0.366	0.451	42.78	
Kubanka	None	.....	9.640	1.692	1.945	3.012	1.751	9.981	62.586	1.392	26.30	10.96	7.440	0.385	0.442	43.72	

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Section 1800 Fertilizer per acre	Amid		Albumin		Gliadin		Glutenin		Total	
		Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent
Defiance	Nitrogen, 80 lbs.....	0.0453	0.2517	0.8774	0.9176	2.0920					
Defiance	Phosphorus, 40 lbs..	0.0453	0.2028	0.5977	0.7877	1.6453					
Defiance	Potassium, 150 lbs..	0.0453	0.2028	0.6071	0.7228	1.5780					
Defiance	None	0.0558	0.1888	0.7084	0.8820	1.8350					
Red Fife	Nitrogen, 80 lbs.....	0.0523	0.1888	0.6654	1.0155	1.9220					
Red Fife	Phosphorus, 40 lbs..	0.0453	0.1678	0.6164	0.7383	1.6680					
Red Fife	Potassium, 150 lbs..	0.0453	0.1748	0.6527	0.8507	1.7235					
Red Fife	None	0.0488	0.1818	0.7015	0.8614	1.7935					
Kubanka	Nitrogen, 80 lbs.....	0.0488	0.2307	0.9162	0.9727	2.1680					
Kubanka	Phosphorus, 40 lbs..	0.0488	0.1888	0.7061	0.7698	1.7135					
Kubanka	Potassium, 150 lbs..	0.0663	0.2028	0.7445	0.9114	1.9250					
Kubanka	None	0.0418	0.2168	0.7318	0.7706	1.7510					

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Variety	Section 1900 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	40 lbs. nitrogen.....	8.650	1.630	2.045	3.473	1.842	10.499	62.568	1.040	26.87	10.96	7.464	0.355	0.421	24.47
Defiance	20 lbs. phosphorus.....	8.730	1.849	1.998	3.282	1.586	9.015	64.818	1.099	20.00	8.24	5.861	0.392	0.446	26.05
Defiance	100 lbs. potassium.....	8.950	1.617	1.905	3.125	1.550	8.835	63.648	1.074	20.73	8.61	5.800	0.362	0.419	29.48
Defiance	None	8.855	1.845	1.895	3.273	1.557	8.875	63.216	1.181	25.83	10.54	7.254	0.415	0.443	25.41
Red Fife	40 lbs. nitrogen.....	8.903	1.605	1.825	3.937	1.953	11.132	63.180	1.161	29.57	12.01	8.336	0.370	0.414	30.64
Red Fife	20 lbs. phosphorus.....	8.973	1.807	1.863	2.915	1.647	9.388	64.917	1.260	22.00	8.94	6.433	0.399	0.430	33.70
Red Fife	100 lbs. potassium.....	9.140	1.865	1.868	3.152	1.751	9.981	63.414	1.289	26.50	10.72	7.486	0.411	0.415	35.60
Red Fife	None	8.925	1.861	1.870	3.051	1.821	10.380	64.044	1.147	27.50	10.80	7.528	0.421	0.451	32.37
Kubanka	40 lbs. nitrogen.....	9.485	1.614	1.835	2.950	1.960	11.172	63.540	1.472	30.30	12.52	8.212	0.351	0.558	40.27
Kubanka	20 lbs. phosphorus.....	8.673	1.677	2.048	2.907	1.786	10.273	63.190	1.438	27.40	11.66	7.929	0.380	0.572	42.84
Kubanka	100 lbs. potassium.....	8.753	1.587	1.985	2.980	1.866	10.636	63.792	1.553	28.13	11.81	7.915	0.391	0.555	42.18
Kubanka	None	10.053	1.862	2.190	2.962	1.731	9.867	64.917	1.488	27.07	12.19	8.111	0.416	0.582	40.97

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Section 1900 Fertilizer per acre	Amid		Albumin		Gliadin		Glutenin		Total	
		Nitrogen Percent	Percent	Nitrogen Percent	Percent	Nitrogen Percent	Percent	Nitrogen Percent	Percent	Nitrogen Percent	Percent
Defiance	Nitrogen, 40 lbs.....	0.0628	0.2098	0.6921	0.8773	1.8426					
Defiance	Phosphorus, 20 lbs..	0.0453	0.1888	0.5931	0.7543	1.5815					
Defiance	Potassium, 100 lbs..	0.0523	0.1958	0.5695	0.7324	1.5500					
Defiance	None	0.0593	0.2098	0.7329	0.5550	1.5570					
Red Fife	Nitrogen, 40 lbs.....	0.0593	0.1888	0.7981	0.9068	1.9530					
Red Fife	Phosphorus, 20 lbs..	0.0384	0.1678	0.7212	0.7196	1.6470					
Red Fife	Potassium, 100 lbs..	0.0523	0.1888	0.6794	0.8305	1.7510					
Red Fife	None	0.0488	0.1748	0.7154	0.8820	1.8210					
Kubanka	Nitrogen, 40 lbs.....	0.0418	0.2237	0.8156	0.8789	1.9600					
Kubanka	Phosphorus, 20 lbs..	0.0488	0.2098	0.7853	0.7421	1.7860					
Kubanka	Potassium, 100 lbs..	0.0280	0.2098	0.7828	0.8454	1.8660					
Kubanka	None	0.0453	0.2098	0.7376	0.7383	1.7310					

ASH CONSTITUENTS OF WHEAT—CROP 1914

Variety	Fertilizer per acre	Sp. gr.	SiO ₂ Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Defiance	80 lbs. nitrogen.....	1.3991	0.016	0.005	0.005	0.033	0.146	0.436	0.012	0.179	0.135	0.346	0.009	0.337	2.092
Defiance	40 lbs. phosphorus.....	1.4166	0.021	0.005	0.004	0.035	0.142	0.431	0.011	0.172	0.133	0.393	0.017	0.376	1.643
Defiance	150 lbs. potassium.....	1.4128	0.016	0.003	0.004	0.033	0.135	0.412	0.009	0.116	0.124	0.375	0.008	0.367	1.578
Defiance	None	1.4174	0.018	0.003	0.004	0.041	0.147	0.437	0.014	0.121	0.137	0.426	0.013	0.413	1.828
Red Fife	80 lbs. nitrogen.....	1.4253	0.011	0.004	0.004	0.030	0.142	0.398	0.011	0.160	0.092	0.364	0.009	0.355	1.922
Red Fife	40 lbs. phosphorus.....	1.4282	0.012	0.004	0.005	0.029	0.145	0.405	0.017	0.123	0.140	0.399	0.016	0.383	1.668
Red Fife	150 lbs. potassium.....	1.4171	0.011	0.004	0.005	0.034	0.146	0.403	0.013	0.112	0.093	0.403	0.014	0.389	1.724
Red Fife	None	1.4241	0.015	0.005	0.005	0.030	0.156	0.437	0.016	0.114	0.119	0.412	0.017	0.395	1.794
Kubanka	80 lbs. nitrogen.....	1.4241	0.012	0.004	0.005	0.032	0.133	0.418	0.016	0.093	0.128	0.343	0.008	0.335	2.168
Kubanka	40 lbs. phosphorus.....	1.4147	0.005	0.003	0.004	0.029	0.134	0.436	0.004	0.093	0.108	0.397	0.008	0.389	1.714
Kubanka	150 lbs. potassium.....	1.4097	0.006	0.003	0.005	0.033	0.143	0.451	0.004	0.144	0.109	0.366	0.005	0.361	1.925
Kubanka	None	1.4171	0.010	0.004	0.005	0.033	0.140	0.442	0.041	0.142	0.123	0.385	0.008	0.377	1.751

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1915

Variety	Fertilizer per acre	Section 1700										True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
		Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent				
Defiance	Nitrogen, 120 lbs.....	10.583	2.125	1.875	4.180	2.1040	11.993	58.520	1.090	29.00	10.88	7.257	0.405	0.537	16.17
Defiance	Phosphorus, 60 lbs.....	10.185	1.958	1.970	3.837	1.5374	8.763	61.632	1.075	18.17	7.03	4.423	0.402	0.447	18.35
Defiance	Potassium, 200 lbs.....	10.480	1.870	1.985	3.732	1.5378	8.765	62.806	0.095	20.00	7.78	5.000	0.391	0.453	22.00
Defiance	None	9.833	1.945	1.923	4.175	1.5447	8.805	62.330	1.022	19.00	7.26	4.586	0.394	0.460	17.77
Red Fife	Nitrogen, 120 lbs.....	9.663	2.025	1.825	3.802	1.9711	11.235	58.605	0.848	30.80	11.82	7.681	0.373	0.516	19.27
Red Fife	Phosphorus, 60 lbs.....	10.233	2.180	1.940	3.195	1.4189	8.088	62.136	0.824	18.30	7.38	4.834	0.410	0.486	23.63
Red Fife	Potassium, 200 lbs.....	9.853	2.246	1.913	3.325	1.5160	8.641	62.551	0.860	21.17	8.39	5.452	0.426	0.506	25.40
Red Fife	None	9.728	2.045	1.920	3.227	1.4119	8.084	62.154	0.842	18.17	7.51	4.926	0.397	0.476	23.54
Kubanka	Nitrogen, 120 lbs.....	9.835	1.855	2.090	3.050	2.2383	13.247	55.093	1.049	41.70	15.48	10.126	0.367	0.487	33.85
Kubanka	Phosphorus, 60 lbs.....	9.655	2.003	2.013	2.940	1.6142	9.721	59.508	0.983	28.90	11.39	7.251	0.398	0.455	35.30
Kubanka	Potassium 200 lbs.....	10.598	2.060	2.023	3.015	1.7401	9.998	59.400	0.955	27.40	10.65	7.065	0.400	0.457	38.85
Kubanka	None	10.603	2.120	2.110	2.955	1.6702	9.645	54.123	1.023	28.70	10.91	7.338	0.384	0.441	36.97

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1915

Variety	Fertilizer per acre	Amid				Glutinin				Total			
		Section 1700	Nitrogen	Albumin	Gliadin	Nitrogen	Nitrogen	Nitrogen	Nitrogen	Percent	Percent	Percent	Percent
Defiance	Nitrogen, 120 lbs....		0.0699	0.1600	0.7627	1.0213				2.1040			
Defiance	Phosphorus, 40 lbs...		0.0418	0.1398	0.5312	0.6845				1.4953			
Defiance	Potassium, 200 lbs..		0.0210	0.1328	0.5149	0.7573				1.5378			
Defiance	None		0.0349	0.1328	0.5289	0.7502				1.5447			
Red Fife	Nitrogen, 120 lbs....		0.0839	0.2307	0.6360	0.8737				1.9711			
Red Fife	Phosphorus, 60 lbs..		0.0558	0.1600	0.4318	0.6671				1.4189			
Red Fife	Potassium, 200 lbs..		0.0593	0.1818	0.4659	0.6865				1.5160			
Red Fife	None		0.0663	0.1678	0.4380	0.6383				1.4119			
Kubanka	Nitrogen, 120 lbs....		0.0628	0.1188	0.8504	1.2361				2.3241			
Kubanka	Phosphorus, 60 lbs..		0.0558	0.0908	0.6641	0.8597				1.7054			
Kubanka	Potassium, 200 lbs..		0.0558	0.1048	0.6176	0.9268				1.7054			
Kubanka	None		0.0558	0.0978	0.6246	0.8713				1.6915			

Variety	Section 1800	Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance		Nitrogen, 80 lbs.....	10.690	1.865	1.818	4.322	2.0128	11.552	58.826	1.071	28.80	11.08	7.292	0.366	0.466	16.97
Defiance		Phosphorus, 40 lbs.....	10.180	1.959	1.965	3.780	1.4814	8.523	61.128	1.027	18.30	7.09	4.252	0.401	0.448	18.42
Defiance		Potassium, 150 lbs.....	8.625	1.777	1.998	3.855	1.4814	8.523	62.946	1.030	20.70	7.97	5.027	0.375	0.416	21.37
Defiance		None	9.953	1.905	1.980	3.912	1.5934	9.162	60.174	1.051	20.50	8.35	4.982	0.383	0.465	18.05
Red Fife		Nitrogen, 80 lbs.....	9.203	1.987	1.860	3.587	1.7679	10.077	60.480	0.794	24.70	9.28	6.244	0.378	0.466	22.05
Red Fife		Phosphorus, 40 lbs.....	9.528	2.022	1.993	3.365	1.4050	8.009	61.988	0.813	18.00	7.27	4.913	0.390	0.471	23.02
Red Fife		Potassium, 150 lbs.....	9.975	1.965	1.813	3.385	1.5478	8.822	62.982	0.829	22.17	8.99	5.829	0.390	0.468	25.30
Red Fife		None	10.085	2.005	2.063	3.312	1.4707	8.383	62.044	0.755	19.40	7.73	5.053	0.390	0.447	24.63
Kubanka		Nitrogen, 80 lbs.....	9.658	1.985	2.088	3.280	2.2383	12.758	54.126	1.046	39.07	15.00	10.089	0.336	0.441	34.14
Kubanka		Phosphorus, 40 lbs.....	9.738	1.835	2.048	3.045	1.6142	9.201	59.436	0.933	26.40	10.81	6.965	0.374	0.425	37.97
Kubanka		Potassium, 150 lbs.....	11.683	1.880	1.850	3.052	1.7401	9.919	60.480	0.941	26.70	10.71	7.011	0.384	0.432	39.75
Kubanka		None	10.898	2.003	1.895	2.950	1.6702	9.520	59.778	0.909	27.50	11.10	7.060	0.391	0.427	38.13

FORMS OF NITROGEN IN WHEAT AS AFFECTED BY FERTILIZERS
—CROP 1915

Variety	Section 1800	Fertilizer per acre	Amid		Albumin		Gliadin		Glutenin		Total	
			Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent
Defiance		Nitrogen, 80 lbs.....	0.0558	0.1740	0.7374	1.0440	2.0267					
Defiance		Phosphorus, 40 lbs..	0.0418	0.1398	0.5312	0.6845	1.4953					
Defiance		Potassium, 150 lbs..	0.0349	0.1460	0.5250	0.6783	1.4953					
Defiance		None	0.0488	0.1538	0.4706	0.8291	1.6073					
Red Fife		Nitrogen, 80 lbs.....	0.0669	0.1958	0.5498	0.8265	1.7679					
Red Fife		Phosphorus, 40 lbs..	0.0628	0.1678	0.4240	0.6454	1.4050					
Red Fife		Potassium, 150 lbs..	0.0663	0.1678	0.4981	0.7141	1.5478					
Red Fife		None	0.0663	0.1678	0.4380	0.6971	1.4707					
Kubanka		Nitrogen, 80 lbs.....	0.0699	0.1398	0.8621	1.0966	2.2383					
Kubanka		Phosphorus, 40 lbs..	0.0523	0.1048	0.5569	0.8477	1.6142					
Kubanka		Potassium, 150 lbs..	0.0628	0.0978	0.5681	0.9764	1.7401					
Kubanka		None	0.0628	0.1048	0.5611	0.8995	1.6702					

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1915

Variety	Section 1900 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	Nitrogen, 40 lbs.....	9.653	1.730	1.905	3.895	1.8800	10.716	59.543	0.960	27.17	10.71	6.612	0.350	0.449	19.00
Defiance	Phosphorus, 20 lbs.....	9.940	1.785	1.985	3.700	1.5378	8.765	62.985	0.999	18.50	7.47	4.752	0.375	0.443	20.92
Defiance	Potassium, 100 lbs.....	10.203	1.577	2.100	3.330	1.4814	8.444	62.895	0.994	20.00	7.92	4.954	0.353	0.462	23.62
Defiance	None	10.085	1.826	1.920	3.797	1.5795	9.003	62.228	1.024	18.70	7.37	4.680	0.380	0.444	19.44
Red Fife	Nitrogen, 40 lbs.....	9.990	1.818	1.869	3.560	1.8521	10.557	59.678	0.963	28.70	10.88	7.478	0.343	0.472	20.96
Red Fife	Phosphorus, 20 lbs.....	10.245	1.820	1.935	3.355	1.4777	8.423	63.094	0.896	19.70	7.82	5.258	0.367	0.457	24.75
Red Fife	Potassium, 100 lbs.....	9.700	1.965	1.943	3.225	1.5409	8.783	63.828	0.833	22.30	8.65	6.219	0.383	0.453	26.89
Red Fife	None	10.043	1.862	1.978	3.347	1.4814	8.444	62.478	0.795	21.00	8.22	5.399	0.361	0.443	25.08
Kubanka	Nitrogen, 40 lbs.....	11.368	1.675	2.005	3.207	1.9919	11.354	57.654	1.051	28.00	11.55	8.073	0.400	0.407	35.35
Kubanka	Phosphorus, 20 lbs.....	11.968	1.785	2.005	2.995	1.6984	9.681	59.004	0.968	25.30	10.36	6.900	0.375	0.430	36.23
Kubanka	Potassium, 100 lbs.....	11.118	1.755	1.910	3.237	1.7262	9.839	60.678	0.959	25.17	10.38	6.851	0.363	0.444	93.13
Kubanka	None	11.425	1.805	1.958	3.000	1.7123	9.760	61.596	0.971	26.07	10.63	7.028	0.396	0.439	36.61

FORMS OF NITROGEN IN WHEAT AS AFFECTED BY FERTILIZERS

—CROP 1915

Variety	Section 1900 Fertilizers per acre	Amid		Albumin		Gliadin		Glutenin		Total	
		Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent	Nitrogen	Percent
Defiance	Nitrogen, 40 lbs....	0.0418	0.1740	0.6508	0.8812	1.8800					
Defiance	Phosphorus, 20 lbs..	0.0349	0.1398	0.4753	0.7829	1.5378					
Defiance	Potassium, 100 lbs..	0.0280	0.1328	0.4890	0.7268	1.4814					
Defiance	None	0.0418	0.1538	0.5172	0.6547	1.5795					
Red Fife	Nitrogen, 40 lbs....	0.0769	0.2028	0.6266	0.8199	1.8521					
Red Fife	Phosphorus, 20 lbs..	0.0628	0.1538	0.4520	0.7181	1.4777					
Red Fife	Potassium, 100 lbs..	0.0628	0.1460	0.5250	0.7239	1.5409					
Red Fife	None	0.0699	0.1740	0.4690	0.6644	1.4814					
Kubanka	Nitrogen 40 lbs.....	0.0769	0.1328	0.6408	1.0855	1.9919					
Kubanka	Phosphorus, 20 lbs..	0.0628	0.1048	0.5569	0.9319	1.6984					
Kubanka	Potassium, 100 lbs..	0.0769	0.0978	0.6106	0.9200	1.7262					
Kubanka	None	0.0593	0.0978	0.6153	0.9014	1.7123					

ASH CONSTITUENTS OF WHEAT—CROP 1915

Section 1800

Variety		SiO ₂	Fe	Mn	Ca	Mg	K	Na	Cl	S	P	N
Defiance	NaNO ₃	0.018	0.005	0.004	0.046	0.149	0.456	0.010	0.083	0.143	0.366	2.0128
Defiance	P ₂ O ₅	0.094	0.010	0.004	0.061	0.132	0.448	0.037	0.073	0.103	0.401	1.4814
Defiance	KCl	0.018	0.005	0.004	0.040	0.141	0.416	0.018	0.084	0.101	0.375	1.4814
Defiance	Check	0.019	0.005	0.004	0.054	0.162	0.465	0.022	0.085	0.100	0.383	1.5934
Red Fife	NaNO ₃	0.058	0.008	0.004	0.038	0.153	0.466	0.024	0.094	0.115	0.378	1.7679
Red Fife	P ₂ O ₅	0.012	0.004	0.004	0.085	0.114	0.471	0.027	0.072	0.094	0.390	1.4050
Red Fife	KCl	0.012	0.004	0.004	0.037	0.147	0.468	0.021	0.090	0.087	0.390	1.5478
Red Fife	Check	0.014	0.004	0.004	0.046	0.141	0.447	0.034	0.063	0.087	0.390	1.4707
Kubanka	NaNO ₃	0.018	0.007	0.004	0.043	0.128	0.441	0.026	0.061	0.102	0.336	2.2383
Kubanka	P ₂ O ₅	0.028	0.006	0.004	0.034	0.133	0.425	0.055	0.048	0.078	0.374	1.6142
Kubanka	KCl	0.026	0.004	0.004	0.032	0.134	0.432	0.026	0.063	0.068	0.387	1.7401
Kubanka	Check	0.022	0.007	0.004	0.035	0.135	0.427	0.029	0.053	0.106	0.391	1.6702

SHRUNKEN KERNELS NOT NECESSARILY HIGH IN PROTEIN

In the preceding tables we have the samples grown during two years of experimentation. Many of these samples, practically all those of 1915, the Defiance samples of 1914, and the samples of both the Fife and Kubanka grown with the application of nitrate are shrunken. These latter samples are not shrunken to anything like the extent of some of the others. I think that it is generally accepted as a fact that shrunken grains are higher than normal in protein. I acknowledge that I thought that this was an established fact. But there is no difference between the badly shrunken samples and the plumper ones that cannot justly be explained in some other manner. The samples grown with the application of nitrates in 1913, carried, in round numbers, 2.0 percent more protein than samples from the other plots. We find on an average a little greater difference in 1915. Our samples of 1913 are all fine, plump wheats, as the weights per 1,000 kernels show. In 1915 they were all more or less shrunken. The Defiance was so badly shrunken that we could sell it only for chicken feed. It would seem unreasonable to consider the excess of protein in the nitrate samples of 1915 due to their shrunken condition, when essentially the same difference existed in the 1913 crop, which was not shrunken. The other shrunken samples of 1915 are all low in protein but they are neither higher nor lower than the less shrunken samples of the same variety grown that season. In fact, the very badly shrunken samples of 1915, differ but little in their protein content from the plump, full-weight samples of 1914. The difference is in favor of the plump samples of 1914. The fact is that the shrunken condition of the samples seems to have nothing to do with the composition, but simply indicates that the process of filling was cut short, and that which would have been a large kernel, remained an incompleated structure. The character of the material, and the amount of it, with which the kernel was filled, was in these cases determined by the rust. The similarity in the composition of the crops of 1914 and 1915 is remarkable. Rust was very abundant in both seasons. The plants were a little more fully developed in 1914 than in 1915 at the time that the rust attacked the plants. The crop was materially better in 1914 than in 1915, but the composition of the wheat was, as stated, very similar. It is not to be understood that we had no fair crops in 1915, for this is not the case. We had as high as 40.8 bushels per acre, weighing 60 pounds to the bushel, and it was only the plots treated with nitrates that yielded crops of either Red Fife or Kubanka that weighed less than 60 pounds to the bushel, some of the Kubanka weighed 63 pounds, but the composition of the wheat was essentially the same as that of the badly shrunken Defiance, weighing from 49 to 53 pounds per bushel.

These results seemed to make it worth the while to determine whether there is any difference in the composition of the large and small kernels of the same samples grown in a favorable season. The samples that we have, which will fulfill this condition, are those grown in 1913. We have arranged in the following table analyses of large and small kernels:

COMPOSITION OF LARGE AND SMALL KERNELS—CROP 1913

Variety	Fertilizer per Acre		Percent of Wheat	Average Wt. per Kernel	Nitrogen Percent	Protein Nx5.7 Percent	Phosphorus Percent	Potassium Percent
Defiance	80 lbs. nitrogen...	large	56.00	0.0397	2.349	12.390	0.395	0.422
		small	44.00	0.0239	2.342	13.347	0.390	0.475
Defiance	40 lbs. phosphorus	large	77.75	0.0417	2.210	12.595	0.444	0.439
		small	22.25	0.0284	1.982	11.299	0.435	0.426
Defiance	150 lbs. potassium	large	74.30	0.0433	2.207	12.582	0.406	0.423
		small	25.70	0.0303	2.014	11.479	0.412	0.413
Defiance	None	large	71.50	0.0425	2.228	12.700	0.412	0.457
		small	28.50	0.0293	2.077	11.837	0.426	0.450
Red Fife	80 lbs. nitrogen..	large	51.60	0.0398	2.637	15.032	0.405	0.467
		small	48.40	0.0289	2.496	14.226	0.405	0.464
Red Fife	40 lbs. phosphorus	large	49.60	0.0391	2.365	13.481	0.456	0.425
		small	50.40	0.0301	2.295	13.079	0.456	0.454
Red Fife	150 lbs. potassium	large	53.10	0.0390	2.447	13.945	0.454	0.413
		small	46.90	0.0318	2.394	13.644	0.426	0.437
Red Fife	None	large	41.00	0.0388	2.457	14.001	0.455	0.440
		small	59.00	0.0306	2.414	13.759	0.462	0.390
Kubanka	80 lbs. nitrogen...	large	45.00	0.0532	2.442	13.920	0.387	0.416
		small	55.00	0.0332	2.433	13.867	0.365	0.423
Kubanka	40 lbs. phosphorus	large	63.66	0.0490	2.141	12.202	0.413	0.463
		small	36.34	0.0339	2.046	11.659	0.396	0.502
Kubanka	150 lbs. potassium	large	65.30	0.0502	2.135	12.167	0.408	0.433
		small	34.70	0.0300	2.068	11.788	0.416	0.438
Kubanka	None	large	69.65	0.0529	2.118	12.073	0.427	0.482
		small	30.35	0.0298	2.085	11.885	0.412	0.474

The table has purposely been made full in the points essential in this case. These small kernels come from the top and bottom of the head and from the middle of the spikelet. We find, in the twelve pairs, a maximum difference of 1.30 percent. There is one other case with a difference of 1 percent. The other ten pairs differ by lesser amounts. The difference, however, is always in the same direction, in favor of the larger kernels. According to these results, neither the shrunken crops, nor the small berries, contain more protein than the large, plump ones.

We have now given the composition of the seed used, that of the three crops so far obtained, and the conditions under which the latter were produced. The Defiance was seed of our own growing, the Red

Fife and Kubanka was seed obtained from the South Dakota Experiment Station. Our own seed was wheat which had been grown on the college farm for many years. The strain is accepted as pure and the variety well established. The Dakota seed was true to variety and pure. It is stated that acclimatization has but little or no influence upon the composition of the crop produced when the seed is transported, as in this case, from one locality to another. I accept this as established and attribute any changes in the character of the crop to local conditions, either of soil, or climatic, or both. The physical characteristics of the first crop were very different from the parent seed, this, however, was true of the crop from our own seed in a certain measure, but not to the same extent as for the crops produced from the Dakota seed. Both the Fife and the Kubanka berries were much larger and different in color. Being curious to learn how the 1913 crops grown in South Dakota would compare in composition with my crops, grown from the same seed, I obtained, through the courtesy of their Department of Agronomy, samples of this crop. My object was not simply to test the effect of change but to assure myself in regard to the effects of my fertilizer experiments, which I shall present later. At the present time I shall endeavor to present the general composition.

GENERAL COMPOSITION OF WHEATS IN 1913, 1914, AND 1915

Under the general consideration of the weather conditions I have pointed out one result which did very great injury, i.e., that these conditions brought about a very severe attack of rust. I have already touched upon the effects of this on the yield and weight per bushel, giving for the latter 62.3, 56.7, and 49.6 pounds in the respective years of 1913, 1914 and 1915. This was for Defiance from the check plots of Section 1800. The weight per bushel of the other varieties was not depressed in 1914 but was slightly depressed in 1915. This indicates that some of the wheat was badly shrunk. Each of the three varieties was severely attacked by the fungus.

Before I give the composition of the wheat for these three years, I wish to again state that my data do not answer the question relating to the effect of planting wheat after wheat on the composition of the second or third crop, and I cannot recall having seen any answer to this question. The growth of the plants, the yield per acre and the weight per bushel have been mentioned as indicating that there was no lack of plant food, but it must be admitted that all of these taken together lack in conclusiveness when we consider the composition.

For our present purpose, i.e., to give a general idea of the composition of these crops, we shall confine ourselves to the amounts of protein, starch, wet, dry and true gluten, and phosphorus. The varia-

tion in the moisture, ash, fat, and crude fiber is too small to play any important part in our present discussion. We shall give the ash constituents to show how little they vary in the three seasons, although the wheats are of very different composition. We shall confine these to the check plots of a single section to avoid, as far as possible, varying conditions and confusion due to different fertilization, and also for the further reason that we have determined the ash constituents in the kernels of one section only. The series of checks given in the following table runs north and south through our land; had it been taken east and west, the individual data would have been different, a fact which we do not wish to evade; but the general results would have been the same, so far as the data actually acquired may be depended on to show:

GENERAL COMPOSITION OF THE SEED USED AND THE CROPS OF 1913, 1914 AND 1915

	Protein Percent	Starch Percent	Wet		Dry		True		Sp. gr.
			Gluten Percent	Gluten Percent	Gluten Percent	Gluten Percent	Gluten Percent	Phosphorus Percent	
Average for Domestic Wheats.....	12.23	.....	26.46	10.31	.....	.....	.....	.....	.....
Average for Foreign Wheats.....	12.08	.....	25.36	9.82	.....	.....	.....	.....	.....
Red Fife, South Dakota, seed crop 1912.....	12.82	59.81	29.33	11.32	8.225	0.279	1.4127		
Red Fife, South Dakota, crop 1913.....	13.27	62.28	28.43	11.41	8.550	0.320	.....		.....
Kubanka, South Dakota, seed crop 1912.....	13.04	61.18	30.93	12.91	9.462	0.326	1.4334		
Kubanka, South Dakota, crop 1913.....	13.32	16.01	29.33	12.37	9.220	0.351	.....		.....
Red Fife, Section 1800, check crop 1913.....	14.43	61.88	28.83	11.55	8.340	0.462	1.4401		
Red Fife, Section 1800, check crop 1914.....	10.22	63.14	25.77	10.42	7.460	0.412	1.4241		
Red Fife, Section 1800, check crop 1915.....	8.38	62.04	19.40	7.73	5.050	0.390	.....		.....
Kubanka, Section 1800, check crop 1913.....	12.05	63.37	25.33	10.63	7.570	0.423	1.4355		
Kubanka, Section 1800, check crop 1914.....	9.98	62.59	26.30	10.96	7.440	0.385	1.4171		
Kubanka, Section 1800, check crop 1915.....	9.52	59.78	27.50	11.10	7.060	0.391	.....		.....
Defiance Seed used.....	13.46	61.47	30.66	11.74	8.504	.....	.....		.....
Defiance, Section 1800, check crop 1913.....	12.14	61.83	25.07	10.22	7.313	0.416	1.4355		
Defiance, Section 1800, check crop 1914.....	10.46	63.14	24.40	10.09	7.000	0.426	1.4174		
Defiance, Section 1800, check crop 1915.....	9.13	60.17	20.50	8.35	4.980	0.383	.....		.....

ASH CONSTITUENTS CALCULATED ON THE AIR-DRIED GRAIN FOR THE THREE YEARS 1913, 1914 AND 1915

	SiO ₂ Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	P Percent
Red Fife, South Dakota seed.....	0.018	0.005	0.005	0.044	0.134	0.490	?	0.086	0.175	0.267
Kubanka, South Dakota seed.....	0.011	0.006	0.005	0.026	0.141	0.468	?	0.064	0.145	0.326
Red Fife, Section 1800, check crop 1913.....	0.017	0.006	present	0.038	0.150	0.444	0.010	0.135	0.113	0.461
Red Fife, Section 1800, check crop 1914.....	0.015	0.005	0.005	0.030	0.156	0.437	0.016	0.114	0.119	0.412
Red Fife, Section 1800, check crop 1915.....	0.014	0.004	0.004	0.046	0.141	0.447	0.034	0.063	0.087	0.390
Kubanka, Section 1800, check crop 1913.....	0.030	0.005	present	0.031	0.137	0.454	0.010	0.130	0.093	0.423
Kubanka, Section 1800, check crop 1914.....	0.010	0.004	0.005	0.033	4.140	0.442	0.041	0.142	0.123	0.385
Kubanka, Section 1800, check crop 1915.....	0.022	0.007	0.004	0.035	0.135	0.427	0.029	0.053	0.106	0.391
Defiance, Section 1800, check crop 1913.....	0.030	0.005	present	0.037	0.141	0.391	0.037	0.060	0.116	0.416
Defiance, Section 1800, check crop 1914.....	0.018	0.003	0.004	0.041	0.147	0.437	0.014	0.121	0.137	0.426
Defiance, Section 1800, check crop 1915.....	0.019	0.005	0.004	0.054	0.162	0.465	0.022	0.085	0.100	0.383

A COMPARISON OF COLORADO AND SOUTH DAKOTA WHEATS GROWN IN 1913

The preceding table gives the most important features in the composition of wheat and the averages for domestic and foreign wheats. Further, it gives the composition of the South Dakota seed and of the crop grown from it in South Dakota, also the same for the crops grown under our conditions. An unbiased comparison of these results leads to the conclusion that in 1913 no changes were produced, which might not have been found in samples grown from our own seed, under our own climatic conditions and on contiguous pieces of land, one-tenth of an acre in area. This is true in the case of all of the data given to show the composition of the samples. The nitrogen determinations were not made by the same analyst that did the earlier work and the ash-analyses were all made by a third one. All nitrogen and starch determinations were done in duplicate, so that neither the differences nor the uniformities which occur are attributable to accidents or errors. The methods used, except those used in determining the mineral constituents, were conventional ones.

The products of the three seasons, grown on the same plots of land and without fertilizers of any kind, vary greatly in their protein, much more markedly so than in their starch content. The highest percentage of starch found in our nine samples of crops grown is 63.37, the lowest 59.78, a range of 3.55 percent for the samples of three varieties of wheat in three years, with an average starch content of 61.9 percent. On the other hand, we have a maximum range of 6.05 percent in the protein, with an average of 10.7 percent. The ratio of starch to protein varies between relatively wide limits from 4.3 to 7.4. This high ratio is evidently due to the suppression of the protein and not due to any unusual increase in the amount of starch. The samples so far considered were grown on check plots and for reasons given above.

The results given for this series of checks taken year by year agree fairly well with the averages obtained for all of the plots, excluding those fertilized with nitrogen.

AN AVERAGE OF THE VARIETIES SECTION BY SECTION

In order to set forth more fully the general composition of the crops, the variation due to variety, and the effects of nitrates, I have averaged the varieties section by section including the check plots with those which received phosphorus and potassium respectively; this fact is indicated by the expression 3/3, meaning the average of these three plots each time. The averages for the nitrates have been made for the sections only. The three varieties are included in each average which is designated in the same manner as the other averages.

AVERAGE COMPOSITION OF WHEAT—CROP 1913

			Protein	Starch	Wet	Dry	True	Phos-
			Perct.	Perct.	Gluten	Gluten	Gluten	phorus
					Perct.	Perct.	Perct.	Perct.
Section 1700	Defiance	3/3.....	11.67	61.67	24.45	9.93	7.05	0.445
Section 1700	Red Fife	3/3.....	13.10	62.19	27.46	11.07	8.00	0.467
Section 1700	Kubanka	3/3.....	12.28	61.07	26.84	11.26	7.91	0.438
Average			12.35	61.64	26.25	10.75	7.65	0.450
Section 1800	Defiance	3/3.....	12.16	62.32	24.69	10.05	7.15	0.422
Section 1800	Red Fife	3/3.....	13.84	61.66	27.68	11.22	8.18	0.460
Section 1800	Kubanka	3/3.....	12.00	62.53	25.78	10.76	7.57	0.414
Average			12.66	62.17	26.05	10.68	7.63	0.432
Section 1900	Defiance	3/3.....	11.14	63.58	22.22	9.23	6.34	0.476
Section 1900	Red Fife	3/3.....	13.97	62.48	28.27	11.47	8.26	0.465
Section 1900	Kubanka	3/3.....	12.63	62.29	25.28	10.87	7.75	0.487
Average			12.58	62.78	25.26	10.51	7.45	0.476
General average all plots								
	without nitrates	.....	12.53	62.19	25.85	10.65	7.58	0.453
Section 1700	Nitrate plots	3/3...	14.89	62.24	34.79	13.77	10.13	0.433
Section 1800	Nitrate plots	3/3...	14.15	60.80	31.21	12.49	9.08	0.446
Section 1900	Nitrate plots	3/3...	13.48	59.76	27.73	11.40	8.12	0.451
General average for the ni-								
	trate plots	.....	14.17	60.93	31.24	12.55	9.11	0.413

AVERAGE COMPOSITION OF WHEATS—CROP 1914

			Protein	Starch	Wet	Dry	True	Phos-
			Perct.	Perct.	Gluten	Gluten	Gluten	phorus
					Perct.	Perct.	Perct.	Perct.
Section 1700	Defiance	3/3.....	8.799	65.14	19.08	8.04	5.66	0.397
Section 1700	Red Fife	3/3.....	9.706	64.51	23.33	9.73	6.86	0.413
Section 1700	Kubanka	3/3.....	10.254	64.93	26.05	10.66	7.65	0.390
Average			9.586	64.86	22.82	9.48	6.74	0.400
Section 1800	Defiance	3/3.....	9.607	63.97	21.61	9.02	6.17	0.398
Section 1800	Red Fife	3/3.....	9.838	63.28	23.49	9.55	6.84	0.405
Section 1800	Kubanka	3/3.....	10.240	64.00	26.12	11.05	7.47	0.383
Average			9.895	63.75	23.74	9.87	6.83	0.395
Section 1900	Defiance	3/3.....	8.908	63.60	22.52	9.13	6.31	0.386
Section 1900	Red Fife	3/3.....	9.913	63.13	25.33	10.15	7.15	0.410
Section 1900	Kubanka	3/3.....	10.280	63.63	27.53	11.89	7.99	0.399
Average			9.700	63.45	25.13	10.39	7.15	0.398
General average all plots								
	without nitrates	.....	9.416	64.02	23.90	9.91	6.91	0.398
Section 1700	Nitrate plots	3/3..	12.174	61.35	31.05	12.83	9.14	0.395
Section 1800	Nitrate plots	3/3..	11.746	61.42	30.88	12.63	8.86	0.351
Section 1900	Nitrate plots	3/3..	10.901	63.10	28.91	11.83	8.00	0.359
General average.....								
			11.607	61.96	30.28	12.43	8.67	0.368

AVERAGE COMPOSITION OF WHEAT—CROP 1915

			Protein Perct.	Starch Perct.	Wet Gluten Perct.	Dry Gluten Perct.	True Gluten Perct.	Phos- phorus Perct.
Section 1700	Defiance 3/3.....		8.78	62.26	19.06	7.36	4.67	0.396
Section 1700	Red Fife 3/3.....		8.27	62.28	19.21	7.76	5.07	0.411
Section 1700	Kubanka 3/3.....		9.79	57.71	28.33	10.98	7.22	0.394
	Average		8.95	60.75	22.20	8.70	5.65	0.400
Section 1800	Defiance 3/3.....		8.70	61.42	19.83	8.47	4.75	0.398
Section 1800	Red Fife 3/3.....		8.40	62.34	19.86	8.00	5.27	0.390
Section 1800	Kubanka 3/3.....		9.55	59.90	20.20	10.70	7.01	0.383
	Average		8.89	61.62	19.96	9.06	5.68	0.390
Section 1900	Defiance 3/3.....		8.74	62.37	19.07	7.59	4.46	0.369
Section 1900	Red Fife 3/3.....		8.55	63.47	21.00	8.23	5.63	0.334
Section 1900	Kubanka 3/3.....		9.76	60.43	25.51	10.46	6.93	0.378
	Average		9.01	62.09	21.86	8.76	5.67	0.360
General average all plots without nitrates			8.95	61.35	21.34	8.84	5.67	0.383
Section 1700	Nitrate plots 3/3...		10.88	58.99	27.99	10.71	7.39	0.364
Section 1800	Nitrate plots 3/3...		11.46	57.81	27.86	11.79	7.87	0.360
Section 1900	Nitrate plots 3/3...		12.16	57.41	33.83	12.73	8.36	0.382
General Average for the Ni- trate plots			11.50	58.07	29.89	11.74	7.87	0.369

There is one big fact evident, namely, that there is a great difference in the composition of the products obtained, whether taken by variety, or by plot. There was a depression of the proteids in 1914, and a further one in 1915. This is not true of the starch, for we find very similar figures for 1913 and 1915, the best and the worst crop. The samples produced with the application of nitrates have been averaged by themselves for the purpose of bringing out the effects of the nitrates in contrast with the more normal samples grown either without any fertilizer, or with such as do not radically disturb the composition of the products.

The data presented in the various tables make it clear that we may safely consider the nitrogen as the element most susceptible to the causes of these differences, and at the same time the most important one. There are differences in the mineral constituents, some of which can be explained, and the ratio of gliadin to glutenin is much closer in the best than in the worst of the three. These may, however, be neglected for the present time and the protein alone be taken into consideration. The starch varies too little in amount and too irregularly to be of much significance, though this too may be affected by the nitrogenous compounds in the wheat. The wet, dry and true gluten are so closely and regularly connected with the total protein that there would be no object in attempting to consider them at all in this connection. It seems probable, then, that, if we can make out what has caused the

differences in the protein content of the three crops we will be justified in asserting that this is the cause that has determined the character of our wheats for 1914 and 1915.

The yield, weight per bushel, and the physical properties of the 1914 crop were all that we could wish, and I had no notion of the existence of any such facts as we find, pertaining to the composition, till the analyses revealed them. This was also in part true of the 1915 crop, for even in this crop 21 of the 24 plots planted to Red Fife and Kubanka yield from 21.95 to 40.83 bushels per acre, and the wheat from these 21 plots weighed from 60 to 63 pounds per bushel, but as appears from the average composition exhibited in the preceding table, the wheat is very inferior.

CAUSES OF INFERIOR WHEAT GROWN IN 1914

The causes which may have produced these results are, in the first place, lack of fertility, in the second place, excess of water and improper temperature which we will include under the term climatic conditions, and in the third place, the rust that developed upon the plants.

Lack of Fertility Not Responsible

In regard to the first cause, we have previously stated that we have no data of such convincing force that we feel entirely satisfied to assert that there might not have been something lacking in this respect, either in the quantity present or in its ratio to other plant foods. Nevertheless, these data convince me most thoroughly that this was not the case. The facts that appear to me as really conclusive that the very low protein content of the wheat in 1914 and 1915 was not due to this, i.e., lack of fertility, are the luxuriant growth of the plants, the yield of wheat, and its weight per bushel.

On the theory that the carbohydrates are deposited at or near the end of the plant's activity, and that the plumpness and weight per bushel depend upon the degree of perfection with which this process is carried out at the time of maturity, it may be suggested, as is frequently stated in the literature of this subject, that the volume of the crop would necessarily correspond to a low protein content. This suggestion does not apply, for in 1913 our Defiance check plots yielded an average of 41.1 bushels, weighing 62.3 pounds per bushel, with 11.86 percent of protein; the same plots in 1914 yielded an average of 31.1 bushels, weighing 56.7 pounds per bushel, with 9.383 percent protein. We need not confine this statement to the Defiance. The Fife plots treated with potassium in 1913 yielded 32.67 bushels per acre, weight per bushel 63.75 pounds, average protein 13.81 percent; the same plots with the same treatment yielded in 1915, 32.16 bushels per acre, weight

per bushel 60.6 pounds, average protein 8.30 percent. The Kubanka check plots yielded in 1913 an average of 34.1 bushels per acre, weight per bushel 63.1 pounds, average protein 12.28 percent; the same plots in 1915 yielded 32.8 bushels per acre, weight per bushel 62.6, average protein content 9.64 percent. An explanation of the difference in the protein content can not be based on the ground that the volume of the crop corresponded to a large increase in the percentage of the starch or other carbohydrates. The percentages of starch remain constant within very narrow limits.

If any deficiency in fertility actually existed, it would probably correspond to the deficiency in the grain and this is in the nitrogen content. The growth and color of the plants ought to reveal any so great a deficiency as would correspond to the depression of the nitrogen that we find. Further, we find direct proof that this is not the case, in that we find a depression in the average amount of the protein present in the grain grown on the respective plots to which a liberal application of nitrogen had been made. We have for the average amount of protein in the grain produced on such plots in 1913, 14.17 percent, in 1914, 11.50 percent and in 1915, 11.50 percent. Some of the samples included in these averages, especially in 1914 and 1915, were badly shrunk and, according to the accepted theory, should have been very high in nitrogen; others of them were, from the physical standpoint, perfect wheats. The amount of nitrogen applied to these plots varied from 40 to 120 pounds per acre, so there could not possibly have been any dearth of nitrogen.

The considerations here presented may fail to satisfy some, but they appear to me to prove conclusively that the cause of the inferior composition of the wheats produced in 1914 and 1915 can not be attributed to lack of fertility.

Cannot Be Charged to Climatic Conditions

The question of climatic influences resolves itself into several phases each of which may be of varying importance, i.e., the total amount of water received by the crop, the manner of application, as irrigating water or as rain, or, stated otherwise, whether the soil alone or both the soil and the plant is wet, the time of application or distribution of the rain, the temperature, cloudiness, winds, etc. The mean temperature and air movement in the years of good and bad wheat were so similar, especially during the month of July and the early part of August, including the period from blossoming till maturity, that it is difficult to believe that these factors were responsible for the differences in the quality of the grain. The mean temperature for July, 1913, was 66.8 degrees, and in 1915 it was 64.7 degrees. The early part of the month in 1915 was warmer than in 1913, but there were great deviations from the mean in either year. There was a

difference in the amount of cloudy weather and the distribution of the water. The amount of water received by the crop during the respective seasons was the same, 19 inches, in 1913 we applied to most of the plots 12 inches of water and the rainfall was 7 inches (6.77), in 1915 we applied 6 inches and the rainfall was 13 inches. This fact relieves me from the necessity of considering the quantity of water used as a cause of these differences, but if it were necessary to do so, I would take the ground that a variation in the amount of water from 12 to 36 inches would not produce these results. We shall discuss this subject later. For the cases in hand, I shall consider the question of the effect of the amount of water eliminated by the fact that the water received during the months of May, June, July and the early part of August, or throughout the growing period of the crop, was so nearly the same that we are justified in neglecting the difference, especially as this difference pertains largely to the month of April, the time of seeding. The fact is that the total water received by the crop of 1915, was less than in 1913, the season when we obtained wheat of the best quality. These considerations justify us in dismissing the direct influence of the climatic conditions as the cause of the poor quality of our 1914 and 1915 crops. It is not intended to deny that the climatic influences affect the quality of wheat crops in some measure, but it is intended to assert that the inferior quality of the crops here considered was not due to the direct influence of climatic conditions.

Rust Chiefly To Blame For Poor Quality

I ascribe the poor quality of the wheat almost wholly to the effects of the rust that developed during the early days of August in 1914 and during the latter part of July in 1915. The earlier varieties of grain apparently escaped serious injury in 1914, when our maximum yield reached 55.5 bushels of wheat, weighing 64.5 pounds per bushel, and our next highest was 54.5 with the same weight per bushel. These two are given because they were obtained with different fertilizers. The rust appeared a few days earlier in 1915 and there was no question about its affecting the yield of each of the varieties. The Defiance was very seriously injured, the yield on one plot was reduced to less than 9 bushels per acre and the kernels were no more than dried out, empty sacks, which, contrary to the statements that I have found on this subject, were not remarkably high in protein, but were 20 percent lower than good kernels grown with the same fertilization on this ground the preceding year. I have found but one analysis of rusted wheat; this was published by Mr. F. T. Shutt, Chemist, Dominion Experimental Farms, Canada, Abstract in Experiment Station Record, Vol. XVI, p. 585. Mr. Shutt gives analyses of rusted and rust-free straw and also of grain. The grain from rust-free wheat contained 10.50 percent proteid, that from rusted wheat 13.69 percent. Mr. Shutt

says of this: "In other words the growth of the rust arrests development and induces premature ripening, which, as we have seen, means a straw in which still remains the elaborated food and a grain small, immature, rich in protein and deficient in starch."

Prof. H. Snyder, in Minnesota Station Bulletin No. 90, Abstract E. S. R., Vol. XVI, p. 1074, gives the analyses of some rusted wheat-straws from which it appears that rust-free straw contains a little over one-half as much protein as badly rusted straw. The Abstract continues: "Wheat from rusted plants contained a higher percentage of protein, fiber and ash than some fully matured grain from rust-free plants grown under the same conditions. The percentage of carbohydrates was highest in the sound samples. Some of the rusted wheat samples contained as high as 19.30 percent of protein." These are the only references to the effects of rust upon the composition of the plant and the grain produced that I have found. McAlpine, in his book "The Rusts of Australia", p. 65, quotes the preceding statement of Shutt's with approval, but adds nothing to it.

Our Results Contrary To Prevailing Opinion

The fact is that we have in 1914 and 1915 wheat which is very similar in composition but very different from wheat produced on the same ground in 1913, and so far I have not given any cause for the difference, but have stated that I believe it to be due to the severe attacks of rust which prevailed during these years. It will be noted that the prevailing opinion is that wheat grown on affected plants is richer in protein than such as is matured on unaffected plants; it is also stated that shrunk wheat is higher in nitrogen than well-filled wheat. This may be correct, but it is certainly not the case with our wheat nor is the percentage of starch perceptibly affected, as is shown by the percentages of starch in the crops of 1913 and in 1915 grown without application of nitrates. The average percentage of starch in the 27 samples of 1913 is 62.2, and for the same number of samples in 1915, grown under the same conditions of fertilization, the average is 61.5. There is a difference of only 0.7 of 1 percent in favor of the crop of higher quality. We must frankly admit that our results are contrary to the prevailing opinion on this subject.

THE NITROGEN CONTENT

In 1913 we studied the development of the nitrogen compounds in the plant from time of blooming till maturity. It is entirely sufficient for our present purposes to follow the course of the total nitrogen. This will be found in detail for the crop of 1913 on page 36 of Bulletin 208. The percentages are given for the fresh plants, but the percentages of dry matter are given on page 34. The variety used for these may be used to recognize the corresponding sample of grain given in

this bulletin. The samples grown with the application of nitrogen are again left out of consideration. The total nitrogen in the stems and leaves remained fairly constant till the end of July, when they showed a very decided decrease, in spite of the fact that the plants were drying out, amounting to from approximately 30 percent to 50 percent. On the other hand, the total nitrogen in the heads ran fairly constant till the end of July, when it suddenly increased from an average of 0.6967 to 0.9868 percent, practically 0.3 of 1 percent in five days (29 July to 4 August) and the head at that time was rapidly increasing in weight. There must have been a very active movement of nitrogen from the plant to the seed at that time. The wheat was cut on 6 and 7 August when it was fully ripe. This wheat averages 12.58 percent protein ($N \times 5.7$).

Low Nitrogen Content In 1915 Due to Rainfall Causing Leaching or Impairing Transpiration

It was impossible for us to repeat this portion of our study in 1914 but we were fortunately able to take it up again in 1915. The full record of this work is given in Bulletin 217. The plants were from 10 to 14 days later in their development and were more succulent than in 1913. The succulency of the plant was probably due to the frequent light rains and heavy dews. The plants are poorer in nitrogen irrespective of the fertilizer applied, even after allowance has been made for the greater quantity of water in the plant. This might be due to three causes, exhaustion of the soil, leaching due to the almost continuously wet condition of the plant, or to a greatly retarded transpiration. Inasmuch as this difference is as great in the case of the plants that were grown with a continuous, artificial supply of nitrogen as in those which were grown without any, it is probably not due to deficiency in nitrogen, and if there be no other causes than those suggested, it must be due either to leaching or to impaired transpiration. This is, in either case, an effect of the weather. The samples of stems and leaves taken from the same set of plots on 29 July, 1913, and 30 July, 1915, were quite close to one another in their nitrogen content, but this was not true of the heads which in 1915 were materially lower than in 1913. It is evident that in both years about this time a very active transference of nitrogen from the plant to the head began. On 27 July, 1915, the heads on the Fife check plot contained 0.5247 percent and on 30 July, 0.6324 percent nitrogen. The drying out of these plants had not yet begun to take place. At about this time in both 1914 and 1915 the wheat became very rusty, but the wheat in 1914 was more advanced, by 5 or 6 days, than in 1915. In fact, we had had up to this time a very favorable season in 1914. This date is the turning point in the character of our respective crops. In 1913 the nitrogen in the plants de-

creased regularly till the wheat was ripe. The stems and leaves dried out and the dry matter increased very greatly, but it was poorer in nitrogen than the plant had been at an earlier date. The heads increased in weight and dry matter, but most of all in nitrogen. On 25 July the heads of plants from plots which had received no dressing of nitrogen contained 0.8495 and the heads of plants from the same plots on 5 August contained 1.2463 percent of nitrogen. Samples taken from other plots between these dates indicate that practically the whole of this change took place between 29 July and 4 August. This wheat was free from rust, ripened naturally and was cut on 6 and 7 August. The average protein content of the samples of this variety grown without the application of nitrogen was 13.63 percent ($N \times 5.7$).

I have pointed out that on 30 July the plants of the 1915 crops contained approximately the same amount of nitrogen as in 1913. From this date till that of full ripeness of the grain, the crops acted entirely differently. There was some increase in the nitrogen of the heads, but it was in no measure comparable to the change that took place in 1913. On 30 July the heads from a check plot averaged 0.6486, on 12 August heads from the same plot averaged 0.7828 percent nitrogen. During 11 days in 1913 we found that the nitrogen in the heads increased from 0.85 to 1.25 percent; in 1915 we found that they increased from 0.65 to 0.78. This apparent increase itself is doubtful when we consider the drying out which took place. On the other hand, we found that the stems and leaves did not diminish in their nitrogen content from this date on till that of ripeness as in 1913. On 6 August, the earliest date on which the leaves and stems were taken together, the average nitrogen content of the plants grown without the application of nitrogen was 0.2371 percent and that of the heads 0.6834 percent; on 12 August the plants and leaves contained an average of 0.2703 and the heads 0.7825 percent. The increase in the heads is at best very small, and, owing to the drying out and relative increase in dry matter, is a little doubtful. This wheat was harvested 16 August in good condition, except for the rust. The average protein content of this wheat was 8.41 percent. This average is 5.22 percent below that for the season 1913.

Rust Was Severe In 1915

We unfortunately were not able to follow this feature of our study in 1914. We can, however, record the fact that we had very favorable conditions up to the end of July, when we had a heavy shower which beat down our grain and rust followed. The grain was more advanced in its development when this happened than it was in 1915 when the rust attacked it. We do not know that the nitrogen transfer was practically stopped in 1914 as it was in 1915. The effect, however, on the composition of the wheat was almost the same. The aver-

age protein content of the 1914 crop for this variety of wheat was 9.82 percent against 13.63 in 1913. This is a very surprising result considering the advanced stage of development of the wheat at the time of the attack. My opinion at the time was that the crop was almost safe against this kind of injury, but it evidently was not. According to our observations of 1913 and 1915 this effect is very probable if the attack took place, as it must have done just at, or during the period of most active transfer. In 1915 the rust was very bad, I have no measure by which I can express the severity of the attack, but it is evident from the data given that it practically stopped the transfer of nitrogen to the heads, which is equivalent to saying the kernels. If it did this in 1915, we argue that it did the same in 1914, and that this is the cause of the low protein content of the grain.

It may be true that the weather influenced the course of the development; it may also be true that the succession of crops may have been ill-advised, still, on 30 July, 1915, the nitrogen in the plants compared favorably in quantity in the stems and leaves with that present in 1913, and had the normal transfer taken place we should have had excellent wheat, for the plants were at this time large and thrifty, and the nitrogenous material already accumulated appeared ample to produce wheat of good quality, but, as we have seen, this did not take place, and we had wheat with 8.41 percent of protein. The observations of Shutt and Snyder on the high proteid content of rusted wheat-straw are in harmony with this view.

We have many samples of shrunken wheat in the crops of 1914 and 1915, but these samples are not high in nitrogen, which we interpret as the natural result of the stoppage of the transfer of the nitrogen. It seems that the movement of the carbohydrates is also interfered with and the shriveled wheat represents practically the condition of the kernel at the time of the attack. Some growth of the kernel takes place after the attack but it is so much less than would normally take place that it does not make the above statement wrong.

Deposition of Nitrogen and Starch Takes Place Simultaneously

This is not the view generally held, so far as I have been able to gather. The prevalent view is that the nitrogenous components of the kernel are the first and the carbohydrates the last to be laid down, so that shrunken kernels are considered to be caused by deficiency of carbohydrates, chiefly starch. I have already called attention to the fact that the percentage of starch in the samples of 1913 and 1915 are very nearly alike, though the weight of the kernels is very different, as the average weight per 1,000 kernels for the respective years may indicate in a general way. The weight per 1,000 kernels in 1913 averaged 38.35 grams, in 1915 26.61 grams, a difference of 11.74 grams per 1,000

kernels, or 44 percent in favor of the 1913 crop. The difference in the average percentage of starch, taking all the samples except those grown with nitrates, is 0.84 percent. One hundred grams of the shrunken wheat contained practically the same amount of starch as a like quantity of the good wheat, and it contained less protein by 3.58 grams. This would seem to indicate that deposition of nitrogen and starch takes place at the same time—or if the deposition of one was hindered more than the other, the deposition of the nitrogen was hindered more than that of the starch.

VARIATION IN AMOUNT OF CRUDE FIBER

No feature in the composition of the crops produced during these three seasons is more marked in its variation than the percentage of crude fiber. In 1913 it was, perhaps, a little below the average for wheat in general—it may be taken roughly at 2.60 percent for 1913—in 1914 it was higher, about 3.00 percent, and in 1915 it was very high, about 3.7 percent. It will be observed that this is roughly inversely proportional to the absolute weight of the wheat. In other words, the frame-work of the cells had been completed and probably but little or no cellulose would under any conditions have been added to the kernels subsequent to the period at which the rust attacked the plants. The rust stopped the transfer of the filling material from the plant to the kernels, and left the ratio of cellulose to the other constituents abnormally high and the kernels shrunken.

The ash, as determined, is probably about 0.1 percent too low, owing to the losses in making the determination, but this loss is common to all the determinations and in the same direction, so that the averages are not very much disturbed. The individual determinations are comparatively close together, ranging in the case of Section 1800 from 1.700 to 1.995 for the year 1913, from 1.692 to 2.017 in 1914, and from 1.777 to 2.022 in 1915. These data include the three varieties and the different fertilizations. The averages for the three years, 1913, 1914 and 1915 are, for the grain grown on Section 1800, 1.925, 1.817 and 1.778 percent of ash respectively. The statement of the ash constituents has been given in percentages of the air-dried grain instead of percentages of the ash, which reduces the numbers given in the statement. Disregarding the chlorine and sulphur in the present statement, the greatest variations will be found in the phosphorus and potassium. These two are perhaps the most important ash constituents, at least they are in our problem, so far as now developed. The average amount of phosphorus in the grain (all three varieties taken) grown on Section 1800 in 1913, 1914, and 1915, was 0.432, 0.388 and 0.382 percent respectively, and the average amount of potassium was 0.441, 0.448 and 0.426 percent. While these averages conceal the differences

in the individual samples, they serve to show that the different seasons, including all the factors, made but little difference in the average percentages of these elements in the grain, though the development of the kernels and their composition, especially in regard to nitrogen, was very different. While I believe, and have so stated, that very small differences expressed in percentages of air-dried grain, very probably have a big significance in regard to the properties of the wheat, and in relation to the effects of fertilizers, and perhaps, also of the seasons. I doubt, however, that we have any data which can be properly so interpreted, still the above averages justify the inference that the relative amounts of ash were not affected greatly by the different conditions prevailing during the three seasons; in other words, the whole development of the plant moved forward in the same manner and relative measure up to the time that the rust interrupted the transfer of matter to fill out the grain. We have no analyses of the plants, giving the ash constituents at such periods in their development that we can use the results in this connection. This is to be regretted, for had we analyses representing plants before and after this period of rapid transfer, it might give us some further useful data.

These results are in close agreement with the conclusions of Brenchley and Hall, who say: "For the filling of the endosperm, each plant possesses as it were a special mould, and continually moves into the grain uniform material cast into that mould, possessing always the same ratio of nitrogenous to non-nitrogenous materials and ash."*

THE EFFECTS OF IRRIGATION

Our object in this work was to ascertain what we may consider characteristic of Colorado wheats and the factors to which this may be due. I have presented the crop of 1913 as probably the most nearly normal wheat that we have grown up to the present time, and I have justified myself in doing so by presenting the abnormal characteristics of the crops for 1914 and 1915, and the causes for the same. One of the factors which enters into our problem is the effect of water, particularly when applied as irrigating water. This question has already occurred in the consideration of the causes for the inferior quality of our 1914 and 1915 crops. In this connection I treated it in the most summary manner, principally because it is a definite and distinct problem. During the seasons of 1913 and 1914 I selected four plots to which I applied a second irrigation four weeks subsequent to the first one and equal in quantity, namely, I aimed to apply 1 acre-foot at each irrigation and to see what effects it produced upon the yield and character of the grain.

* W. E. Brenchley and A. D. Hall, "Development of the Grain of Wheat," *Journal Agricultural Science*, Vol. 3, Part 2, p. 215; also *Rothamsted Memoirs*, Vol. 8.

Our experiments yielded no results that we could interpret as showing conclusively that this amount of water made any difference in the yield, weight per bushel, or composition of the grain. There were differences in the composition of the grain from the different plots, but they were small and irregular, so that we attributed the differences observed to the differences in the plots themselves and not to the differences in the amount of water applied.

I learned, very fortunately, that a systematic study of the effects of the fertility of the soil upon the duty of water and at the same time the effects of different amounts of water upon the amount of grain and dry matter produced, was being made at Boise, Idaho, by the U. S. Department of Agriculture, Irrigation Investigations. I further learned that they were not studying the effects of these conditions upon the composition of the grain. Mr. Don H. Bark, the irrigation engineer in charge, was kind enough to furnish me with samples of the grain produced, together with detailed cultural notes. The samples represent two years work and constitute most excellent material illustrative of this subject, especially the samples of the second year, which were grown wholly under Mr. Bark's supervision.

The samples representing the first year's work were produced under a co-operative system. The variety grown in 1913, the first year, was Dicklow spring-wheat. There was no perceptible difference in the physical properties of these kernels. They were all plump, but many of them were small or only medium in size and the weight per bushel was generally less than 60 pounds; some samples were as low as 52 pounds. The time from planting till harvest was in most cases 128 days.

SPRING-WHEAT, BOISE, IDAHO

Spring-Wheat	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Dicklow, 0.76 ft. water applied.....	0.0140	0.1328	0.4892	0.7909	1.4269
Dicklow, 1.31 ft. water applied.....	0.0245	0.1258	0.5021	0.8798	1.5322
Dicklow, 2.28 ft. water applied.....	0.0280	0.1328	0.4892	0.8137	1.4637
Dicklow, 0.71 ft. water applied.....	0.0558	0.1678	0.5660	0.8728	1.6624
Dicklow, 1.00 ft. water applied.....	0.0314	0.1748	0.3880	0.8824	1.4766
Dicklow, 1.24 ft. water applied.....	0.0280	0.1748	0.5825	0.7228	1.5081
Dicklow, 0.99 ft. water applied.....	0.0245	0.1608	0.4974	0.8728	1.5555
Dicklow, 1.62 ft. water applied.....	0.0245	0.1818	0.5300	0.8367	1.5730
Dicklow, 2.33 ft. water applied.....	0.0245	0.1818	0.3806	0.9681	1.5550
Dicklow, 0.66 ft. water applied.....	0.0245	0.1608	0.5440	0.8546	1.5839
Dicklow, 1.39 ft. water applied.....	0.0280	0.1398	0.4194	0.7493	1.3365
Dicklow, 2.19 ft. water applied.....	0.0245	0.1748	0.4361	0.7946	1.4100
Dicklow, 2.34 ft. water applied.....	0.0349	0.1748	0.4917	0.8669	1.5683
Dicklow, 2.68 ft. water applied.....	0.0280	0.1748	0.4986	0.8206	1.5220
Dicklow, 3.28 ft. water applied.....	0.0314	0.1888	0.5184	0.8694	1.6080
Winter-Wheat, Boise, Idaho					
Turkey Red, 0.47 ft. water applied...	0.0628	0.1398	0.5383	1.1122	1.8531
Turkey Red, 0.89 ft. water applied...	0.0488	0.1468	0.5756	1.1836	1.8548
Turkey Red, 0.93 ft. water applied...	0.0384	0.1818	0.5721	1.0766	1.8689

Amount of Water Applied Does Not Affect Protein Content

These wheats are not shrunken, but the kernels are very uneven in size. It will be noticed that these wheats are a little higher in starch than our samples for 1913, when our Defiance on Section 1900 averaged 63.58 percent though the other varieties averaged lower, 61 and 62 percent. The percentage of true gluten is very low. The average percentage of phosphorus is lower than in our wheats and that of the potassium is markedly higher. These differences are consistent throughout the series of samples representing the Dicklow variety. To what these differences may be due is not the question that the samples are presented to answer, the question is: "What has been the effect of different amounts of water?" The table shows that the range in the percentage of crude protein is from 7.181 to 9.476, a difference of 2.3 percent. Is this difference due to the amount of water added, or is it due to differences in the land on which the wheat was grown? The wheat carrying 9.476 percent protein was grown with 0.71 foot of irrigating water, which is the lowest amount applied, except in one case, and this, with the least amount of water, produced wheat with 9.028 percent protein. The lowest percent of protein, 7.181, is found in wheat produced with the application of 1.39 acre-foot; with these exceptions the wheat runs uniformly within a limit of 1 percent, which may be due to differences of soil, for these samples were grown by different parties who were co-operating. We have pointed out that two of the wheats with high percentages of crude protein were pro-

duced with less than 0.75 foot of water to the acre. On the other hand, the second highest percentage of protein, 9.156 percent, is found in wheat produced with the application of the maximum amount of water, 3.28 feet to the acre, and the next highest percentages occur with the application of 1.62 and 2.34 feet. The total range of the percentages of protein is so limited and the differences that we find being no greater than is found on different plots of land of the same character, and receiving the same treatment, we consider that these experiments, in so far as they are conclusive, indicate no relation between the amounts of water applied and the percentage of protein contained in the kernels. The total lack of any relation between the water applied and the variation of the percentage of protein produced, supports this view.

The winter-wheat given was harvested 340 days from planting. How much water fell as rain during the autumn and winter months is not given in the notes, nor is the date of ripening, but I take it that this date and that of harvesting were close together. This wheat is plump, with a great deal of yellow-berry or mealy wheat. The yields for irrigated wheat were very low, 3.7, 12.29 and 17.5 bushels to the acre. The amounts of water applied as irrigating water were 0.47, 0.89 and 0.93 acre-foot, and the analyses throughout are almost identical, showing a low percentage of protein for this variety, 10.6 percent, but it is very near the percentage that we have found for samples of dry land wheat, and higher than some exceedingly mealy samples of this variety. We have found, generally, about 13.0 percent of protein for this variety of wheat grown with irrigation.

The experiments of 1913 were not entirely satisfactory to Mr. Bark, so he endeavored to make those of the next year more satisfactory to himself and, for my purposes they are much more conclusive.

An Additional Test at Boise, Idaho, In 1914

The experiments here described were made on six plots of land, each approximately one-tenth of an acre in area. These plots were arranged in two series of three each, the series abutting on one another. One series was not fertilized, the other received an application of well-rotted horse and cow manure at the rate of 15.67 loads to the acre. The land was plowed in November, harrowed and disced in the spring, seeded 2 April, and corrugated 4 April. Wheat practically all up by 25 April. One plot in each series received the same amount of water, i.e., they were paired, one manured and one unmanured. One of these pairs received one acre-foot, one 2 and one 3 acre-feet of water. The manured plots yielded as follows per acre: With 1 acre foot of water, 4,033 pounds of straw and 1,467 pounds of wheat; with 2 acre-feet of water, 4,228 pounds of straw and 1,663 pounds of wheat; with

3 acre-feet of water, 3,489 pounds of straw and 1,826 pounds of grain. The unmanured plots yielded as follows: One foot of water, 1,713 pounds of straw and 1,000 pounds of wheat; 2 feet of water, 2,183 pounds of straw and 1,144 pounds of wheat; 3 feet of water, 2,511 pounds of straw and 1,266 pounds of wheat. The distribution of the water was as follows: Those plots that received 1 foot of water were irrigated 2 June, 19 June, and 16 July, those that received 2 feet of water were irrigated 21 May, 11 June, 26 June, 8 July and 15 July; those that received 3 feet of water were irrigated 11, 20 and 29 May, 12 and 25 June, 3 and 15 July. The grain was ripe by the 24th or 25th of July, or 114 days from planting. The plots were harvested as soon as ripe and the grain threshed 11 August. The variety used this season was the Marquis. The grain without exception was good. The individual kernels were of good size and well filled, 1,000 kernels from the unmanured plot that received 2 feet of water weighed 33.90 grams, and from the corresponding manured plot 35.77 grams. I judge the latter to be the very best of the six samples. All of the samples contain many half-mealy or mealy berries. No distinction can be made in this respect between the grain grown with or without manure, without a very careful count which, owing to the color of the berries, would be very difficult to make with any high degree of accuracy. If any distinction can be made between the samples in this respect, the second sample given above may be the least affected of the six. This was grown on a manured plot with 2 feet of water. The analyses of these samples including the ash constituents follow:

SAMPLES OF WHEAT GROWN WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO—CROP 1914

Variety	Water applied Per acre	Manure applied Per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Marquis, 1 foot (1.05)	None	.....	8.833	1.857	2.103	3.185	1.839	10.423	63.198	1.249	26.50	11.37	7.669	0.450	0.406
Marquis, 1 foot (1.07)	15.7 loads	.....	8.398	1.804	2.175	3.140	1.853	10.557	61.794	1.507	25.33	10.94	7.381	0.449	0.422
Marquis, 2 feet (1.94)	None	.....	8.790	1.878	2.075	3.120	1.846	10.519	62.820	1.178	27.73	12.44	8.079	0.454	0.401
Marquis, 2 feet (2.01)	15.7 loads	.....	8.608	1.943	2.068	3.170	1.897	10.813	63.144	1.249	27.30	11.75	7.864	0.452	0.408
Marquis, 3 feet (2.99)	None	.....	8.608	1.928	2.120	3.062	1.846	10.519	62.406	1.306	27.67	11.83	8.005	0.456	0.422
Marquis, 3 feet (3.05)	15.7 loads	.....	8.648	2.009	2.090	3.035	2.047	11.931	61.472	1.346	27.33	11.42	7.904	0.458	0.405

WHEAT GROWN WITH AND WITHOUT MANURE AND WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO

Variety	Water applied per acre	Manure applied per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gladiin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Marquis	1 foot (1.05)	None	0.1223	0.1958	0.6372	0.8831	1.8385
Marquis	1 foot (1.07)	15.7 loads	0.0453	0.1888	0.6975	0.9227	1.8525
Marquis	2 feet (1.94)	None	0.0628	0.1958	0.7014	0.8855	1.8455
Marquis	2 feet (2.01)	15.7 loads	0.0593	0.1958	0.7003	0.9316	1.8970
Marquis	3 feet (2.99)	None	0.0453	0.1818	0.7330	0.8854	1.8455
Marquis	3 feet (3.05)	15.7 loads	0.0523	0.2307	0.7260	1.0375	2.0465

MINERAL CONSTITUENTS OF WHEAT GROWN WITH AND WITHOUT MANURE AND WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO—CROP 1914

Variety	Water applied Per acre	Manure applied Per acre	Sp. gr.	SiO ₂	Fe	Mn	Ca	Mg	K	Na	Cl	S	Total Inor- ganic P	Total Organic P
Marquis 1 ft. water	None	.....	1.4204	0.032	0.006	0.006	0.038	0.154	0.406	0.027	0.086	0.104	0.455	0.034
Marquis 1 ft. water	15.7 loads	.....	1.4283	0.028	0.005	0.006	0.043	0.150	0.422	0.035	0.100	0.114	0.447	0.036
Marquis 2 ft. water	None	.....	1.4307	0.028	0.007	0.005	0.042	0.156	0.401	0.053	0.089	0.123	0.454	0.040
Marquis 2 ft. water	15.7 loads	.....	1.4336	0.050	0.006	0.006	0.047	0.156	0.408	0.056	0.072	0.119	0.452	0.036
Marquis 3 ft. water	None	.....	1.4193	0.045	0.006	0.005	0.038	0.161	0.422	0.067	0.101	0.124	0.456	0.032
Marquis 3 ft. water	15.7 loads	.....	1.4173	0.054	0.006	0.005	0.036	0.158	0.405	0.035	0.096	0.078	0.458	0.029

Owing to the prevalence of mealiness in the kernels, mentioned in the last paragraph before the table, we would expect a rather low percentage of crude protein, but, according to our previous observations, we would not expect any noticeable increase in the starch. We have given, among our general samples, three of this variety grown at Fort Collins on fallowed ground, and with one irrigation. These are higher in protein but quite similar, in regard to the starch, to the Idaho samples. The protein in our samples is 13.8, 14.0, and 16.0, while the starch is 59.1, 60.2, and 59.9 percent. Our samples received but one irrigation, about 12 June, which was probably at the rate of 1 foot to the acre, or perhaps less. The Idaho samples received from three to seven applications of water, aggregating from 1 to 3 feet. At the present we will consider the Idaho samples by themselves. The applications of 2 and 3 feet of water increased both the yield of straw and wheat, and the manure effected a further increase. The unmanured plots yielded 1,000, 1,144 and 1,266 pounds of wheat per acre with 1, 2 and 3 feet of water; the manured plots yielded 1.467, 1.663 and 1.826 pounds with the respective applications of water. The effects upon the amounts of straw were relatively the same. From the standpoint of dry matter produced, it is evident that there is an increase due to the more liberal application of water. The manure produced an increase in crop and the application of larger quantities of water produced its own effect, which was slightly enhanced by the influence of the manure. This phase of the question is mentioned merely for the purpose of taking cognizance of the facts in the case and not for the purpose of discussing them. The feature that I want to present is: What, if any, was the effect of the different quantities of water applied upon the composition of the grain? The preceding statements will be deemed as sufficient so far as the crop is concerned.

Experiments of 1914 Give Practically the Same Results as In 1913

These analyses, when compared with one another, do not show any differences in composition which can be attributed to either the water or the manure. By common consent, justified by the facts, we look to the nitrogen content as the key to the solution, but we may in this case take all of the constituents one by one, and we will arrive at the same conclusion, i.e., that there is no variation due to these factors of sufficient size to justify serious consideration. It is true that there is a shadow of difference in the amount of protein present in favor of the produce from the manured plots reaching 1.4 percent in the case of the manured plot that received 3 feet of water. That 15.67 loads, probably not far from 16 tons, of well-rotted manure per acre should have so little, practically no effect upon the composition of the grain, is a little surprising at first sight. The water was applied, as has been stated, at different intervals up to within ten days of full maturity.

This, as we have learned from the study of the changes of the nitrogen in the plant, would be just about at the beginning of the period of most active transfer of the nitrogen from the plant to the berry. The plots that received 1 foot of water had three irrigations, those that received 2 feet had five, and those that received 3 feet had seven. These latter had an irrigation at intervals of nine or twelve days. The ground must have been quite wet all of the time, as the average amount applied at one time must have been about 5 inches, but the wheats from these plots do not differ in their nitrogen content; the plot that received 1 foot of water in three applications produced wheat containing 10.423 percent of protein and the one that received 3 feet of water in seven applications produced wheat with 10.519 percent protein. Neither the amount of water nor the distribution of it has affected the protein content of the wheat. It might be better to state that both together have produced no effect upon the composition of the wheat. It goes without saying that this wheat was kept growing all the time and never suffered for moisture. The supposition is that the weather was bright and favorable. The element next to nitrogen in its sensitiveness to the relative food supply is probably phosphorus, which rises and falls inversely with the nitrogen; in this series it is uniformly very high, and just as high in the manured plots as in the unmanured ones. Attention is called to this particular feature at this time, for the good reason that I intend to point out that comparatively small amounts of nitrogen in the form of nitrates produce marked effects upon the composition of the wheat.

Results In Colorado and Idaho Identical

The results of these two seasons of experimentations are altogether consistent with the results obtained with our own samples of 1913 and 1914, one a season of high and the other of low quality in our wheat. As these Idaho experiments were carried out in a much more systematic manner than ours, I shall content myself with these and omit ours.

These facts and results apply in answering the question relative to the effects of the distribution of the moisture, raised in discussing the causes for the poor composition of our 1915 crop, in which, after citing the fact that our crops of 1913 and 1915 were grown with practically the same amounts of water, I said: "This fact relieves me from the necessity of considering the quantity of water used as the cause of these differences, but if it were necessary to do so, I would take the ground that a variation in the amount of water from 12 to 36 inches would not produce these results."

Water and Manure Affect Volume of Crop, But Do Not Affect Composition

If we admit the samples of Turkey Red grown in Idaho to a place in these series of experiments, we have a range in the water used from

0.41 foot to 3.28 feet, without discovering that the amount of water *per se*, provided that the plant does not actually suffer for the want of water, has any influence upon the composition of the wheat, or this influence is so small that it is concealed by the influence of the other soil factors. Both the amount of water and the manure had an influence upon the volume of the crop, but no influence upon its composition.

Knowing nothing to the contrary, I assume that the weather was bright and the plants themselves were uniformly dry exteriorly, and grew in sunshine and with good ventilation, that is, there was no lodging and the air circulated freely between the plants. The total rainfall at Boise, Idaho, for May, June, July and August, 1914, was 2.39 inches.

WHY PROTEIN CONTENT IS MOST SIGNIFICANT FACTOR IN THIS STUDY

I have followed others in considering the amount of protein contained in the grain the most significant compound for the purposes I have had in view. This is justified, both by the important part that it plays in the use to which the grain is put, principally bread-making, and also by the fact that it varies greatly in quantity in proportion to the amount present. The starch, which in its total quantity exceeds the protein by four or five times, varies less as a rule than it. The method of determining the nitrogen is, probably, the most accurate one used in the ordinary analysis of the grain, so that it forms the best single analytical criterion for the estimation of the probable quality of the wheat. The other compounds are present in relatively small proportions and small percentage variations may really have great significance in regard to the living processes of the plant, but they are more difficult both to establish and to interpret. A plant physiologist, perhaps, might make out the reasons for, and the significance of the fact that the crude fiber in the Marquis wheat may vary 0.70 percent when grown in different localities. But, considering the difficulties in making this determination a real close one, and the fact that the amount of the fiber which is largely contained in the bran varies but little from 2.8 percent, it would seem, in the main, unwise to give this constituent any prominence. The same may be said of the phosphorus, but not with the same justice, for the determination can be made with an exceedingly high degree of accuracy and though its quantity is small, this quantity can be shown to bear a general relation to the amounts of other substances present in the grain and eventually in the soil. In Ohio Bulletin 221, p. 22, for instance, the author, J. W. Ames, says: "Phosphorus applied to the soil, showing a deficiency of this element as measured by crop yields, increases the amount of phosphorus in

the grain. Associated with this increased amount of phosphorus there is an increased quantity of potassium and a decreased amount of nitrogen." Another conclusion is formulated as follows: "The percentage of nitrogen in the wheat plant varies with the supply at its disposal, and is also influenced to a considerable extent by the supply of phosphorus." p. 23. This observation of Ames is undoubtedly correct, but I have omitted, in the preceding discussion, reference to these facts, preferring to consider the more evident and commonly considered features, though not necessarily the more important ones.

THE EFFECTS OF THE VARIOUS ELEMENTS OF PLANT FOOD UNDER OUR CONDITIONS

Nearly all of our data has been presented but up to the present time I have given consideration to such subjects as have been forced upon me by the questions arising from the conditions that prevailed in the different seasons. There has been no neglect of the object had in view when we planned the experiments, but the questions presented had to be answered in some manner before we could discuss those which our experiments were made to answer. Without first answering the questions that we have present we could not answer the ones that we wished to discuss, i.e., What are the effects of the respective elements of plant food under our conditions? The answer to this question is necessary in order to approach the primary question of our investigation, to-wit: Why do wheats soften, if they do, under our conditions?

At the present time we can discuss only the questions of composition and physical properties, and if to any degree at all, only incidentally, any matter pertaining to the baking qualities of the flour. Our experiments resolve themselves into three experiments repeated four times with each of three varieties of wheat each year; namely, a check plot and three others, one of which received an application of potassium, one phosphorus and one nitrogen. The fundamental data are, of course, taken to be those furnished by the check plots. In making this choice of arrangements I fully appreciated that it was a purely gratuitous assumption that our check plots would yield normal wheat for our conditions. But this seemed to be a matter of some indifference, for the character of the wheat produced on the plots receiving the individual fertilizer would be like that produced on the check plot or they would be either better or worse, and as we repeated this nine times a year with each of the fertilizers we hoped to find out what effect the individual plant foods produce under our conditions. As has already been pointed out, climatic and pathological conditions intervened which produced very serious results. I have presented these results to the best of my ability and I hope in an entirely unprejudiced manner. It remains for me to present the effects produced by these fertilizers as I believe them to be shown by our data.

In planning this work, I of course, proceeded on certain assumptions. I firmly believed, and still believe, that the development of unusual amounts of nitrates in our soils in the Arkansas Valley accounted for the deterioration in the quality of the sugar beets between the years of 1898 and 1910. I succeeded in showing that the application of nitrates produced those properties in the sugar beets that constituted the points of inferiority in the deteriorated beets—late ripening, characteristically shaped beets, low sugar content, and juices that produced much molasses and which crystallized with difficulty.

There is no reason for concealment of the fact that I thought it probable that this characteristic of our soil might be in part or wholly responsible for the weakness complained of in our wheat. Any collection of samples of Colorado wheats, taken at random, will make it perfectly evident that some other factor than climate or irrigation is at work in determining the character of the wheat, for samples of the same variety from the same locality vary exceedingly in the color, size, shape and hardness of the kernels, and further, in their protein content.

It is very common to characterize wheat kernels according to their appearance as flinty and mealy. This mealiness is designated in many of our states as yellow-berry. I cannot state that the general complaint of softening referred specifically to the yellow-berry kernels, but rather to a general fact that our flour does not yield enough bread. Nevertheless, I am sure that some millers regard the two terms as indicating the same condition. At the present time I do not intend to present the milling and baking qualities of these wheats, as these constitute distinct problems, though incidental reference to some features of them may be almost unavoidable.

Mealy Kernels Result If Available Nitrogen Is Too Low

There is no question but that this difference in the appearance of the kernels of the same variety corresponds to a difference in composition, a fact recognized, so far as I know, everywhere at the present time. Schindler in "Der Getreidebau" (1909) p. 151, cites P. Holdfleiss as showing in 1900 that such kernels differ by 2.44 percent in protein. We have discussed this condition in regard to its cause in Bulletin 205 and from the physical results alone came the conclusion that this condition in the kernel was to be attributed to the ratio between the available nitrogen and available potassium. If the available nitrogen is too low, mealy berries are produced. In previous pages of this bulletin I have discussed the view put forward by some that this condition is due to the amount of water applied as irrigation, and have given my reasons for rejecting it.

There is one statement in that discussion, however, that deserves further consideration. It is the statement asserting the manner in

which an excess of water may act in bringing about this mealy condition of wheat, namely, by diluting the nitrates.

Lawes and Gilbert, discussing the effects of rain on the wheat crop, say: "It has of course long been known that an excess of wet is injurious to the wheat crop, but it is only comparatively recently that one at least of the material causes of the adverse influence has been clearly made out; namely, the great loss of nitrogen carried off by drainage in the form of nitrates."*

I have shown, in Bulletin 208 and again in Bulletin 217, the extent to which the nitrates may be washed out of the soil by an irrigation. Further, it has been stated that the application of 40 pounds of nitrogen per acre applied at the time of planting produced the characteristic effects of the nitrates though an irrigation of 1 acre-foot was applied on 12 June, nearly a month before the plants came into bloom. We have also demonstrated how efficient such an irrigation is in removing the nitrates from the upper portions of the soil, and further, the rate at which they are re-established in our soil, knowing very well, that this rate depends upon the nitrifying efficiency of the soil with which we are dealing.

VARIATION OF NITRIC-NITROGEN IN SOIL AFFECTS MEALINESS OR STARCHINESS OF CROP

There is another way of looking for the cause of this mealiness and flintiness in the kernels; this is to ascertain whether the characteristic differences in the composition of these kernels can be produced at will by the fertilizers applied. If so, the cause will be more firmly established. We have given, in the table "The Composition of Yellow-berry and Flinty Kernels Grown Under Identical Conditions", fifteen pairs of analyses made on kernels of these characters selected from the same sample of grain. We find that the flinty berries are uniformly higher in total nitrogen, true gluten, gliadin and glutenin than the yellow-berry kernels. We find the same difference, only in a slightly greater degree, between the wheats grown with the application of nitrates and the averages for all the other samples. In 1913 we have, for the average of all the samples grown without the application of nitrates, 12.53 percent protein and 7.55 percent of true gluten, for the samples grown with nitrates 14.17 percent protein and 9.11 percent true gluten; in 1914 we have 9.42 percent protein and 6.91 percent true gluten for the samples grown without and 11.61 percent protein and 8.67 percent true gluten for those grown with the application of the nitrates. In 1915 we have 8.95 percent protein and 5.67 percent true gluten for the samples grown without and 11.50 percent protein and

* "Our Climate and our Wheat Crops," Rothamsted Memoirs, V.

7.87 percent true gluten for those grown with the application of the nitrates. We have, then, a characteristic distinction in the composition of these wheats which is independent of the weather conditions, at least within the extent that they varied in these three seasons, and also independent of the pathological effects produced by the rust. I have explained that I attribute the depression of the average percentage of protein from 12.53 in 1913 to 8.95 in 1915 to the direct influence of the rust and do not believe that the weather has much direct influence upon it. Of course, I do not assert that it had no influence, but I think that this influence was negligible compared with that of the rust. The effect of the rust was certainly as severe in the case of the grain produced with the application of nitrates as in that of the others, in fact it was certainly much more severe if the effect is proportional to the abundance of the parasite on the plant. The differences given for the protein in the wheats grown with and without nitrates are 1.64 percent in 1913, 2.22 in 1914, and 2.55 in 1915. These figures represent the crop. There were almost no mealy berries in the samples grown with the nitrate, but in the other samples there were a great many, up to 96 percent, mealy or half-mealy berries. The differences found in the crops, taken in mass, are about the same as those found for the flinty and mealy berries selected out of the same samples. The table given to show this difference shows that the Kubanka, in which a much sharper division of the flinty and mealy kernels is possible than in the case of the Fife, presents a variation of this difference, ranging from 1.9 to 2.7 percent. We produced the flintiness in one crop, and with it the increase of nitrogen, by the application of sodic nitrate or nitric-nitrogen. The same difference is found in the flinty kernels selected from the produce of the other plots. I attribute it to the same cause. If it be asked whether I assert that the nitric-nitrogen varies enough from place to place in a piece of land to produce this result, I answer yes. This is the explanation that I offer for the facts presented by Prof. Montgomery in Bulletin 269 of the Bureau of Plant Industry, and is my answer to the questions which he formulates as follows: "Why should one plant growing under practically the same environment as another, collect from the soil two or three times as much nitrogen?" Prof. Montgomery continues, giving answer to suggested, but unexpressed questions: "The three plants are from the same mother growing in the same centgener probably less than two feet apart, yet the actual grams of nitrogen gathered differ more than 100 percent. This difference is not inherited as these plants rarely transmit this quality." The uniformity of environment, the fertility of the soil being included, was only apparent. The temperature, moisture, winds, sunshine may have been identical, but not the supply of available nitrogen. The witnesses to this fact are the percentages of nitrogen in the mature wheat. This is in perfect accord with the facts that we find pertaining to the

distribution of both total and nitric-nitrogen within limited areas. We selected 150 square feet, forming an area 5 x 30 feet, and took from the middle of each foot a core 2 inches in diameter to a depth of 1 foot, and determined the total and nitric-nitrogen in each sample. We found but few samples from adjacent square feet that did not vary both in the total and nitric-nitrogen, sometimes by significant quantities. We found, for instance, in two contiguous square feet, total nitrogen 0.13600 and 0.14552 percent, and nitric-nitrogen 8.33 and 14.18 p. p. m. We found as low as 6.02 p. p. m. nitric-nitrogen in 1 square foot. This gives us a difference of 5.83 p. p. m. nitric-nitrogen in contiguous areas, 1 foot square, and a maximum range of 8.16 parts in 150 square feet. I made the statement, just above, that the total and nitric-nitrogen varied by significant quantities. In using this expression I am not begging the question by using general terms. The fact is that I do not know, and no one else, so far as has come to my knowledge, has even made an attempt to determine, how small a quantity of nitric-nitrogen in the soil may affect either the quantity or quality of the wheat produced. But we have shown the effects of 10 p. p. m. of nitric-nitrogen, reckoned on the surface-foot, applied to the wheat at planting time. That a less quantity will affect the growth and composition of the crop is very probable, for this quantity was sufficient to produce plants showing the effects of over-feeding in a very marked degree. This amount produced lodging to the very line to which it was applied, it produced broad-leaved, green plants with weak lower nodes, small, often shrunken, kernels and increased the protein in the grain by approximately 2 percent in every case of its application, excepting one or two, in the three years that we have been conducting these experiments. Twice the amount of nitric-nitrogen, 20 p. p. m., produced a greater effect by about 0.7 percent and three times the amount, 30 p. p. m., produced a further increase of about the same amount in the average composition of the crops. The variations, then, in the amounts of nitric-nitrogen within an area of 150 square feet, being about 8 p. p. m., are sufficient to account for the variations observed by Prof. Montgomery, and also to account for the occurrence of flinty and starchy kernels in the same lot or sample of wheat.

MANURE HAS NO EFFECT ON AMOUNT OF YELLOW-BERRY OR COMPOSITION OF GRAIN

There is one feature made evident by the Marquis samples grown at Boise, Idaho, in 1914, which requires discussion in this connection. I have pointed out that the application of water in quantities varying from 1 to 3 feet made no difference in the composition of the wheat, and had no effect upon the prevalence of the yellow-berry in the samples. At the same time, as will not escape the notice of some, the ap-

plication of 15.67 loads of well-rotted manure produced no effect either on the amount of the yellow-berry, or upon the composition of the wheat in two out of the three cases. The third case, standing against the two others, and being moderate in amount, is not sufficient to preclude almost any other explanation.

It is not a new observation that the application of farmyard manure may increase the yield of both the straw and grain without affecting the composition of the latter. Ritthausen and Dr. R. Pott, after stating that it has been frequently observed that the liberal application of nitrogenous manures generally increases the protein in the mass of the plant produced, and adding that this has been proven beyond doubt, for root crops, potatoes, beets, etc., continue: "The results that have been obtained in growing grains (Samen) have proved much less definite.

While the older investigations of Hermbstaedt* and Boussingault† show that wheat and rye seed increase notably in their protein content on the liberal manuring of the soil with substances rich in nitrogen, those of John in Hohenheim and further those instituted by Lawes and Gilbert yield contrary results, according to which the content of these substances (protein) in the seeds is more or less depressed, and A. Mueller finds in the analyses of barley, grown after different manuring, no essential difference in the composition.‡

"It accordingly appears doubtful that manuring with nitrogenous substances exercises a definite influence upon the protein content of the seed."‡

Ritthausen and Pott used sodic nitrate and ammonic sulphate as nitrogenous manures in their experiments and found an increase of 32.0 percent in the amount of nitrogen in the harvested grain. They take the average percentage of nitrogen present in the unfertilized plots as 100 and the average found for those fertilized with nitrogen was 132.

Some of these experiments were made eighty-odd years ago, but we have the same results now as then. The effect of farmyard manure is at best doubtful, so far as the composition is concerned, but not at all in regard to the crop. The data given by Kosutany|| show that farmyard manure does not always increase the nitrogen contained in the berry. The increase shown in his two pairs of analyses is 0.31 and 1.69 percent of protein respectively. The latter difference may have been due to the effects of the manure, but Ritthausen and Pott obtained an increase of 5.19 percent of protein by the use of nitrogen as sodic nitrate or ammonic sulphate.

* Schweigger Journ., 46-278-285; Erdmann Journ. fuer tech u oekonon, Chemie XLL, 1-53 (1832). See also Wolff die chemischen.

† Boussingault, die Landwirthschaft, 1. p. 290-291.

§ Stockhardt Zeitschrift, fuer deutsche Landwirthe (1855) p. 172-174.

‡ H. Ritthausen and Dr. R. Pott. Die landwirthschaftlichen Versuchs-Stationen Vol. XVI. p. 385, Author's translation.

|| Kosutany Der ungarische Weizen und das ungarische Mehl pp. 171-172.

NITRIC-NITROGEN INCREASES NITROGEN CONTENT AND PRODUCES FLINTY KERNEL

Our results in 1913, a favorable year, showed a gain from 0.57 to 3.36 percent of protein, but there was in every case in which the sodic nitrate was applied a greater or smaller increase. Similar results were obtained in 1914 and 1915, but the maximum differences were a little greater. The different results obtained with farmyard manure, amounting in some experiments to contradictions, may be due to the form in which the nitrogen is present, or to the nitrifying efficiency of the soil. It appears to be certain that nitric-nitrogen, or easily nitrifiable ammoniac nitrogen, increases the nitrogen content of the grain and produces flinty berries; this is not the case with farmyard manure, or if farmyard manure ever produces flinty berries with an increase in the nitrogen content, it is not uniform in its action, for it certainly does not always do it, while the nitric-nitrogen does.

The statements previously made, regarding the composition of flinty and yellow-berry wheats selected out of the same samples, and concerning the composition of flinty wheat grown with the application of nitric-nitrogen, and yellow-berry wheat grown with the application of potassium, justify me in making the following statements without going into the details of many analyses. The application of nitric-nitrogen produces flinty kernels, an increase of protein, amounting in some cases, to more than 2.0 percent, and a corresponding increase in the true gluten. The same relation exists between the starch present in the flinty wheat produced by the nitric-nitrogen and in the wheat grown with the application of potassium as exists between the percentages of this substance in flinty and mealy kernels sorted out of the same sample. In regard to the mineral constituents, there is usually a little more potassium in the mealy samples than in the flinty, especially in normally developed berries. The phosphorus is depressed by the application of nitrogen, to which statement we have found but few exceptions; on the other hand, it cannot be said that potassium has increased it. This suppression of phosphorus is exhibited, not only by our samples grown with the application of nitric nitrogen, but also in samples of flinty wheats from other sections when compared with yellow-berry wheat from the same section. This statement applies to the crop and is not based on selected kernels. The samples here referred to were grown in the immediate neighborhood of one another and on the same type of soil, so the questions of climate and type of soil are eliminated. The flinty wheat, in this case, contained 0.114 percent less phosphorus than the yellow-berry sample. The flinty sample was grown on land so rich in nitrate that an ordinary aqueous extract of the soil reacted strongly for nitric acid with ferrous sulphate and sulphuric acid. The yellow-berry crop in this case contained 50.0 percent more phosphorus

than the flinty crop. These two crops, grown with irrigation, show in a very marked manner the composition characteristic of the two classes of wheat. Our dry-land wheats are usually winter-wheats, but they show this difference in physical properties and these characteristics in their composition, so it is not a question of water supply. Another dry land sample of Turkey Red presents as marked a case of yellow-berry as any sample of this wheat in my possession, and contains only 9.04 percent of protein, while the other samples of yellow-berry wheat of the same variety, grown with irrigation, contained 9.65 and 10.05 percent protein. Irrigated wheat of the same variety, grown in the same section of country as the latter two, and from the same lot of seed, contained 13.21 percent of protein, but it was all flinty. The mills willingly accepted this sample, but objected to the former. These samples are good illustrations of my previous statement that the phosphorus is usually lower in the flinty wheats, in which the flintiness is directly due to the influence of nitric-nitrogen. We have in the last two yellow-berry wheats, 0.309 and 0.345 percent phosphorus; the flinty wheat, which undoubtedly owed its flintiness to nitrates in the soil, contained 0.231 percent. They also serve to illustrate the other statement that the potassium is usually a shade higher in the yellow-berry wheats than in the flinty ones, in the yellow-berry samples we have 0.539 and 0.561 percent potassium, in the flinty samples we have 0.485 percent. The statement previously made was based upon results with spring-wheats. These Turkey Red wheats were grown with a water supply ranging from 6 inches of rainfall to 6 inches of rainfall plus one good irrigation during the season in which the wheat ripened.

We have just seen that a scarcity of water does not prevent yellow-berry, which is used in this connection as indicative of composition, as much as to indicate a physical condition. We have also shown that much water does not produce it, and further does not affect the composition of the wheat under ordinary conditions. I am at the present time satisfied that under some conditions, a too liberal supply of water would produce changes in the composition of the wheat, but for all ordinary conditions I let the above statement stand unmodified. I will repeat some data already given to show to how great an extent I am justified in making this statement. I have two samples of spring-wheat, one of Defiance, the other of Red Fife, which were grown without irrigation and with a rainfall of 6.77 inches. These samples contained 13.92 and 15.20 percent protein respectively. A sample of the latter variety grown with irrigation and grown close to the last one given, within 150 feet, contained 17.14 percent protein, while the seed from which the Defiance sample was produced, grown with irrigation, contained 14.92 percent of protein. A very much fairer test of the effects of the amount of water upon the prevalence of yellow-berry

and the composition of wheat is the Marquis wheat grown at Boise, Idaho, of which I will give in this place only three samples; the one grown with 1 foot of water contained 10.423 percent, the one grown with 2 feet of water contained 10.557 percent and the one grown with 3 feet of water contained 10.519 percent of protein. The other features of their composition were just as close to one another as are the percentages of protein. The other three samples in this series were heavily manured with farmyard manure and two of them are identical with the three already given. The third one differs slightly in its percentages of crude protein, but is the same in its true gluten, so that five of the six samples are identical in their composition, and the sixth one is at most uncertain. These samples are all strongly affected with yellow-berry and are very high in both phosphorus and potassium, but the potassium is not quite so high as in the Dicklow spring-wheat, which is very mealy and very rich in potassium. The averages for the Marquis are, potassium 0.416, and phosphorus 0.454, for the Dicklow, the potassium is 0.506 percent.

The question may be raised whether 1 foot of water may not suffice to produce the maximum amount of change in the composition of the wheat. In this case the results obtained by the addition of the second and third foot of water would be wholly inconclusive. Again, it may be asked whether the distribution of the water was such as to make the test of the different quantities of the water conclusive. I think that the data given affords an affirmative answer to the latter and to the former also. But I may give the results obtained with a plot of Marquis wheat at this place. This plot was fallowed ground. It received one irrigation, 1 foot or less of water. The yellow-berry was less than 15 percent, protein 15.998 percent and phosphorus 0.374 percent. The Boise samples, manured and not manured, that received 1 foot of water were practically 100 percent mealy and half-mealy, contained 10.42 and 10.56 percent protein and 0.450 and 0.449 percent phosphorus respectively. The weather conditions were equally favorable in the two cases.

In addition to this, the fact that we can grow, on the same tract of land, using the same quantity of water, either flinty or starchy crops with their characteristic composition as we will, proves that flintiness and starchiness are not products of the weather, or dependent upon the water supply in quantities up to 36 inches, we may say 42 inches, for we should add six inches of rainfall.

We have now discussed the effects of potassium and nitrogen without separating them or specially designating them. We have also considered fully the effects of water applied as irrigating water. We have further considered the effects of farmyard manure, which has the effects of a potassic rather than those of a nitrate manure. Further

we have suggested that frequent light rains and heavy dews may have a different action on the plant than many times their volume applied to the soil. We have shown in Bulletin 217 that the transfer of nitrogen from the plant to the head is practically inhibited by an attack of rust. We have shown in this bulletin that the protein content of the grain is greatly depressed by such an attack. We have also pointed out that the composition of the shriveled wheat is not different from plumper wheat produced under similar conditions, and that the protein and starch are transferred to the kernel at the same time. Further, that the period of rapid transfer is brief; in 1913 it apparently extended over a period of five days. Further, that in 1915 this transfer did not take place, not directly because of the weather, but because of the rust, *Puccinia graminis*, which attacked the plants severely at this time. We have given the gluten, especially the true gluten, to show its intimate relation to the crude protein, also the phosphorus and potassium in all the samples to show their dependence upon and relation to the composition of the wheats. We have said nothing about the effects of phosphorus for the reason that in our soils, under our conditions, it has failed to produce such effects that we believe can be interpreted; in other words, its effects upon the growth of the plant, the ripening of the grain, and the character of the wheat produced have not been decided enough, that is, they have not been of sufficient magnitude, to justify us in entertaining even tentative judgments relative to them, in fact, we are compelled to doubt whether this element has exerted any influence at all. We have carefully avoided, and even disclaimed, any opinion relative to the milling and baking qualities of these wheats, though we have found it convenient to give the gluten for the purpose stated above, and have given the gliadin, glutenin, etc., for future reference. In regard to the hardness and softness of the varieties experimented with, we have given their crushing strength in considerable fullness. The statement of these results is possibly due the reader, but he must put his own value on them. I cannot see that any useful fact has been established by the data acquired.

We have shown in grams the difference in the crushing strength of the flinty and mealy berries as given by this method. This difference varies from 3,000 to 5,000 grams, but it is doubtful whether this corresponds to the differences in composition or quality of the wheat. The suggestive fact that I have in mind is this: The Kubanka, as grown on our land with irrigation, is a hard wheat, i.e., has a high crushing strength; the averages obtained vary from 17,000 to 19,000 grams. The Red Fife, for samples grown in the same season on adjacent plots, yields a crushing strength of 10,000 grams. The Kubanka was lower in its protein content than the Red Fife. This difference does correspond to a difference in the deportment of the two wheats

in the mill, the Kubanka working very unsatisfactorily in a short reduction. This is due to the difference in the manner of breaking into gritty meal. The miller may know how to eliminate this difference by varying his tempering process. We have offered no explanation for the difference in the deportment of the Red Fife and Kubanka on drying at 100 degrees C. for seven hours, the crushing strength of the one being regularly increased, and that of the other decreased rather than increased, for the sufficient reason that I know of no reason to offer. The kernels are certainly effectively dried on being heated at 100 degrees C., under a pressure of not more than 75 mm. for seven hours.

SUMMARY

Our conclusions in the matter are as follows:

That the wheat plant is much more easily influenced in the character of its product, seed, by the soil fertility than we have been taught to believe.

That the individual elements of plant food exercise specific influences on the composition of the grain produced.

That nitrogen in the form of nitric-nitrogen in the soil affects the growth of the plant, increasing the nitrogen in both the plant and the seed.

That nitric-nitrogen influences both the composition and the character of the grain, producing in the latter respect the characteristic designated as "hard" wheat, i.e., small, flinty, translucent, dark-colored berries, relatively rich in nitrogen.

That these characteristics have a deeper significance in the plant metabolism than the production of an increase of a few tenths of one percent in the nitrogen content of the berry.

That the mineral constituents contained in the berry are influenced by the amount of nitric-nitrogen available to the plant.

That the mineral constituents of the plant are also influenced by the amount of nitric-nitrogen available to the plant, but to a different extent and not necessarily in the same direction as in the berry.

✓ That the nitric-nitrogen produces a soft, weak straw, causing lodging, both by producing a heavy growth of leaves and an elongation of the upper portions of the plant, and by causing a weakness in the lower nodes of the plant.

That nitric-nitrogen greatly increases the susceptibility of the plants to the attack of the rust fungus, probably by furnishing a better

nutrient and also because of the softness characteristic of such plants, which is probably due to the weakness of the cell walls themselves.

That organic nitrogen in farmyard manure does not produce these results, except in the measure that it is converted into nitric-nitrogen, the rate of which process depends upon the nitrifying efficiency of the individual soil.

That our results do not show that potassium has increased the starch; neither do they show that it has had any positive effect on the quantity of this substance formed.

That potassium has a tendency to suppress the nitrogen content of the berry.

That potassium suppresses the nitrogen in the plant throughout its growing period, particularly in the stems and leaves, but does not appear to suppress it in the head.

That potassium, under our conditions, produces an effect upon the development of the plant as shown by the larger size of the plants at a certain stage of development, but the plants on the other plots attain the same degree of development a few days later, eliminating this difference.

That potassium increases the condition designated as yellow-berry.

That phosphorus under our conditions has produced so little effect that no interpretation is possible.

That the phosphorus in the berry is depressed by nitric-nitrogen but is not affected by potassium.

That manganese is uniformly present.

That the amount of water applied as irrigating water may increase the crop, but has so good as no effect upon the composition of the crop produced.

That the leaching effect of irrigating water on the nitrates in the soil is not sufficient to affect the nitrogen content of our wheat, if first applied when the plants are two months old, or two months after the application of the nitrates.

That frequent light rains, when associated with heavy dews, produce different effects on the plant from those produced by irrigating water applied to the soil.

That the time of the rainfall and the weather conditions succeeding, are the most important factors in determining the effects of rain upon the wheat.

That the importance of these conditions is an indirect, rather than a direct one, depending upon the development of rust or its failure to develop.

That there is a period just before the maturing of the plant, when, under favorable conditions, the plant transfers its substance to the berries.

That the effect of rust is practically to inhibit this transfer.

That, for the production of the best wheat, there exists an optimum ratio between the nitric-nitrogen and available potassium in the soil.

That, if the potassium predominates, yellow-berry is produced.

That, if nitric-nitrogen predominates, soft, weak plants, small, flinty, and often shrunk berries result.

That, so far as the crushing strength is a proper criterion whereby to judge, our wheats range from semi-hard to hard.

That, so far as composition is concerned, our wheats, produced under normal conditions, i.e., when the plants are free from rust, stand well above the average.

That our soil varies in character to such an extent that there is no general average composition of the wheat produced that can be considered characteristic.

That our climatic conditions are so favorable that differences in composition are, for the most part, attributable to other immediate causes.

That rust causes a very marked depression in the protein content of the wheat, even if the crop is well advanced at the time that the rust attacks the plants.

That rust increases the percentage of crude fiber in the wheat by preventing the filling out of the berries.

That the effects of the fertilizer upon the composition of the wheat and the production of flinty berries, or the increase in the yellow-berry, are not eliminated or concealed by the unfavorable conditions that we had in 1915.

That, on the other hand, the effects of the nitric-nitrogen in increasing the protein content of the wheat was rather emphasized thereby.

That, in 1915, we have shown three classes of effects in the plants, those due to fertilizers or soil, those due to weather and those due to rust.

That of these, those due to rust were by far the most marked and were prejudicial in their character.

That the effect of rust on the grain is to prevent the transfer of the filling material to the berries.

That the shrunk berries due to this cause are not high in protein.

That small berries sifted out of normally developed crops average a little lower in protein than the large berries.

That fixation proceeds in our soil rapidly enough to furnish a sufficient amount of nitrogen to become an important factor in our problems.

That nitrification proceeds rapidly enough to more than quintuple in five months, the amount of this form of nitrogen in the soil at harvest time. The actual increase was from the equivalent of 43.2 to that of 232.7 pounds of sodic nitrate from August to December, 1915.

APPENDIX

The analytical methods followed in the work presented in this bulletin differ in some respects from those given in our manuals. This is true to such an extent that I feel it incumbent upon me to give my methods, in justice to myself, and in order that others may prove the work presented, if they wish to do so, by the same methods that I have used.

The preparation of the ash of either the wheat straw or wheat kernels, involves the loss of important elements, phosphorus, sulfur and chlorine, therefore it seemed desirable to avoid this tedious work and the losses.

I believe that Leavitt and LeClerc were the first to call attention to the material loss of phosphorus in incinerating wheat kernels*. My own experience has taught me that the loss of phosphorus due to volatilization renders it almost impossible to make duplicate phosphorus determinations by incineration that agree reasonably well no matter at how low a temperature one may char the wheat.

The loss of phosphorus during the burning of the straw is much more marked. It is impossible under the joint action of the silica and carbon to expel the phosphorus so completely that only traces of it, a few thousandths of one percent, remain. The determinations not given in the following notes were made by the usual conventional methods, and are therefore omitted.

THE DETERMINATIONS OF IRON, CALCIUM, MAGNESIUM AND THE ALKALIS

These determinations were effected as follows: One or more portions of 25 grams of wheat were treated with concentrated nitric acid in separate portions of 15 to 20 c.c. The mass foams strongly and, if too much nitric acid be added at one time, one is apt to lose the portion, unless an unduly large dish be used. I used a 4-inch silica dish. The whole was evaporated down to a gummy mass before the addition of the next portion of acid. When 50 c.c. had been added, the residue was heated for a while in a hot-air oven, though this is not necessary, and then charred over a free flame and finally put into the muffle. Most of the carbon was burned out. The mass, still containing carbon, was treated with *aqua regia*, the solution evaporated to dryness, the residue treated with hydrochloric acid and filtered. The filter containing the residual carbon and silica was returned to the dish and burned and the residue treated as before. The united filtrates contained all of the bases as phosphates. The silica, together with any crease-dirt, consisting of fine sand, remained on the filter. The total silica and crease-dirt was so small in quantity that no attempt was made to separate them. An examination, however, with an ordinary pocket lens, suffices to show the presence of sand grains.

* Journal Am. Chem. Soc. Vol. 30, pp. 391-394.

The only objection against the use of silica dishes was the fact that small flakes sometimes broke loose and were weighed as silica. The amount of silica this adds to that of the wheat is extremely small and is usually negligible.

The iron, calcium and magnesium were precipitated as phosphates. The iron was weighed as phosphate, the calcium as oxid and the magnesium as pyrophosphate.

The alkalis remained in the filtrate from the precipitate of the phosphates of iron, lime and magnesia. The filtrate was concentrated, and if still alkaline, was acidulated with hydrochloric acid. An excess of ferric chlorid was added and then ammonia in excess to throw down the ferric oxid and with it the phosphoric acid. The precipitate was filtered off, washed, dissolved in hydrochloric acid and reprecipitated. The united filtrates contain the alkalis as chlorids. The procedure from this on was as usual.

The calcic oxid obtained in the above manner is always slightly brown, due to the presence of manganese. It is very probable that the magnesia is also always contaminated in a slight degree.

The chlorin was determined in a separate portion of 10 grams or more.

The portion of wheat taken was dissolved in a mixture of nitric acid and argentic nitrate. When the wheat was completely dissolved and only a white flocculent precipitate remained, water was added, which materially increased the precipitate. This precipitate contained the whole of the chlorin as silver chlorid or otherwise. It was filtered off, washed in part (washing is not necessary when sucked sufficiently dry by the pump), the mass impregnated with a mixture of potassic nitrate and sodic carbonate, transferred while still moist to a nickel dish containing two or three grams of the deflagrating mixture on which the fully opened filter was placed, covered lightly with the mixture and the whole heated until the mass was completely fused. The amount of the deflagrating mixture used was from five to seven grams. The fused mass was dissolved in water and the usual method for the determination of chlorin followed. The fusion is so quickly made that chlorin, if present in the gas, can cause no appreciable error in the results.

The phosphorus was also determined in a separate ten-gram portion.

The wheat was dissolved in concentrated nitric acid and one and a half grams of magnesian oxid added. The whole was evaporated to a brown gummy mass and ignited. The amount of magnesia added is not sufficient to cause the complete combustion of the organic matter, but the mass burns without deflagration. The cooled and partly white mass was treated with dilute nitric acid, or wet with water, and concentrated acid added, evaporated again, and the combustion completed. The magnesian oxid containing the phosphate was dissolved in nitric acid and evaporated with sulfuric acid to separate silicic acid and the phosphoric acid precipitated as molybdate, and finally weighed as magnesian pyrophosphate.

The sulfur was determined in the same manner as the phosphorus, except that ordinary gas could not be used, either in evaporating or igniting. I used electricity for the former and gasoline for the latter purpose. The magnesian oxide was dissolved in hydrochloric acid. If the magnesian oxide be heated in the muffle, care must be exercised that it does not attain too high a temperature or a loss of sulfuric acid may occur.

The manganese was determined colorimetrically. The wheat was destroyed by nitric acid as in the other instances. The combustion was completed in the muffle, the residue taken up with sulfuric acid and filtered. Any carbon that had escaped combustion was burned off and the residue dissolved in sulfuric acid and added to the first filtrate. The solution contained about 5.0 percent of sulfuric acid. A few milligrams of silver sulfate were added as a catalytic agent. A few grams of ammoniacal persulfate were then added and the solution heated in a boiling water bath so long as the color deepened.

THE ANALYSIS OF WHEAT PLANTS AND WHEAT STRAW

The analyses of these substances present some difficulties. To determine the ash, I took 10 grams of the ground straw or plant, charred thoroughly and extracted three times with boiling water, then burned out the carbon as completely as possible and extracted again with water as thoroughly as possible. The residue was ignited and weighed as insoluble ash. This portion is seldom white and an examination under the microscope shows the siliceous outlines of the cells inclosing particles of carbon. The water-soluble portion of the ash contains from 25 to 30 percent of its weight of silicic acid. The terms soluble and insoluble ash mean but little in this case. Their sum gives the total ash, less the phosphorus, which in this process may be so good as wholly lost by volatilization. Hydrochloric acid will extract from the insoluble ash obtained in this way about 0.1 percent of the weight of the straw.

For the analysis proper, I took 100 grams of the ground straw and proceeded as above, except that I extracted the charred mass with hydrochloric acid, as it extracts less coloring matter than water. The charred and extracted mass was pulverized, the carbon burned out as far as possible and the residue again extracted with hydrochloric acid. This residue was ignited and considered as pure silica, though it was not white. The hydrochloric acid extracts were evaporated to dryness to separate silicic acid that had gone into solution. The weight of this was added to the insoluble silica and their sum was considered as total silica. The hydrochloric acid solution was made up to 250 c.c. An aliquot part, from 60 to 100 c.c. according to the quantity of soluble ash found in the sample, was taken for further manipulation. A few cubic centimeters of a ten-percent solution of ammoniacal phosphate were added and the bases precipitated by the addition of ammonia, to which a little ammoniacal sulfide was added to carry down traces of manganese and, possibly, zinc. The manganese and zinc were present in such small amounts that no further attention was paid to them at this time.

The separation of the bases and the determination of the alkalis were effected just as in the case of the wheat.

Phosphorus

I took 25 grams of finely ground straw, disintegrated thoroughly with concentrated nitric acid, added $1\frac{1}{2}$ to 2 grams magnesian oxide, evaporated down, and finally heated to introduce the combustion. The residue was not white, but contained much unburned organic matter. Nitric acid was added and the previous operation repeated. The residue, if still too dark, was burned white in the muffle. The thoroughly burned mass was dissolved in nitric acid, a few cubic centimeters of concentrated sulfuric acid added and evaporated, at last, on the sand-bath till the sulfuric acid fumes began to escape, the dish was then placed in a hot-air oven and kept at 160° or higher to separate the silicic acid. The phosphoric acid was separated from this solution with the usual precautions by ammonium molybdate and eventually weighed as magnesian pyrophosphate.

As the silicic acid may give some trouble, this may be removed by digesting the disintegrated straw with 10 to 15 c.c. of strong hydrofluoric acid before the addition of the magnesian oxide.

Sulfur was determined in essentially the same manner as the phosphorus, except that gas cannot be used unless free from sulfur, and the magnesian oxide, which must not be heated too strongly, was taken up with hydrochloric acid and evaporated to separate silicic acid.

The manganese in the straw was determined in ten-gram portions in the same manner as in the wheat, except that to the thoroughly disintegrated mass was added a few c.c., 5 or 6, of concentrated hydrofluoric acid to remove the silica; the mass was then heated for 10 minutes, when I added 5 c.c. concentrated sulfuric acid and continued the evaporation, heating at last over the free flame. The residual mass of carbon usually burned out readily in the muffle.

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